RESTRICTED ORDNANCE PAMPHLET No. 1056

26

TORPEDO DATA COMPUTER

MARK 3, MODS. 5 to 12 Inclusive

A BUREAU OF ORDNANCE PUBLICATION JUNE, 1944

TORPEDO DATA COMPUTER

MARK 3, Mods. 5 to 12 Inclusive

DEPARTMENT OF THE NAVY
BUREAU OF ORDNANCE

TABLE OF CONTENTS

TORPEDO DATA COMPUTER

Fig. 1

MK. 3 MODS. 5-8 AND 10-12 INCLUSIVE

FIRE CONTROL EQUIPMENT

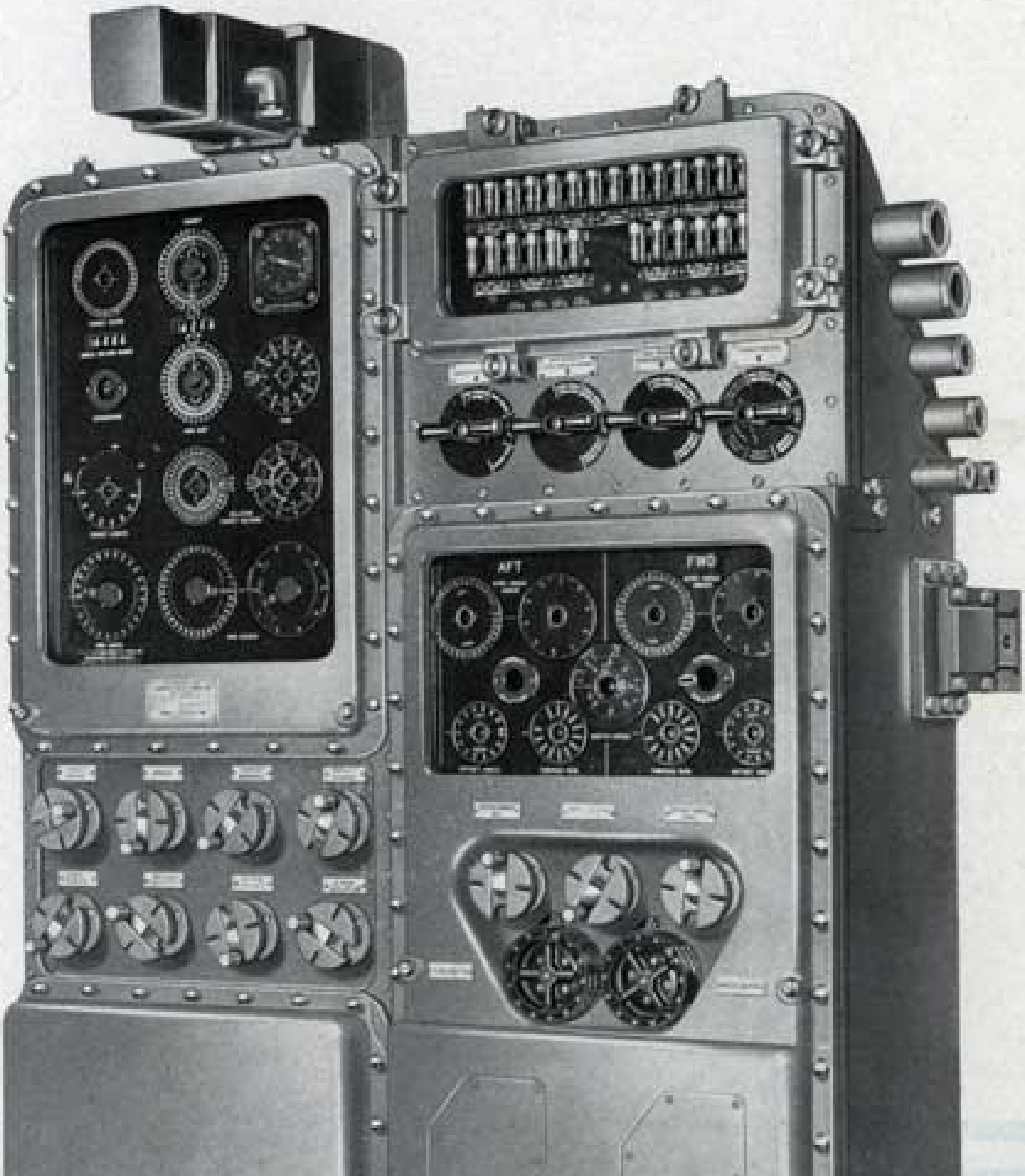


Fig. 2

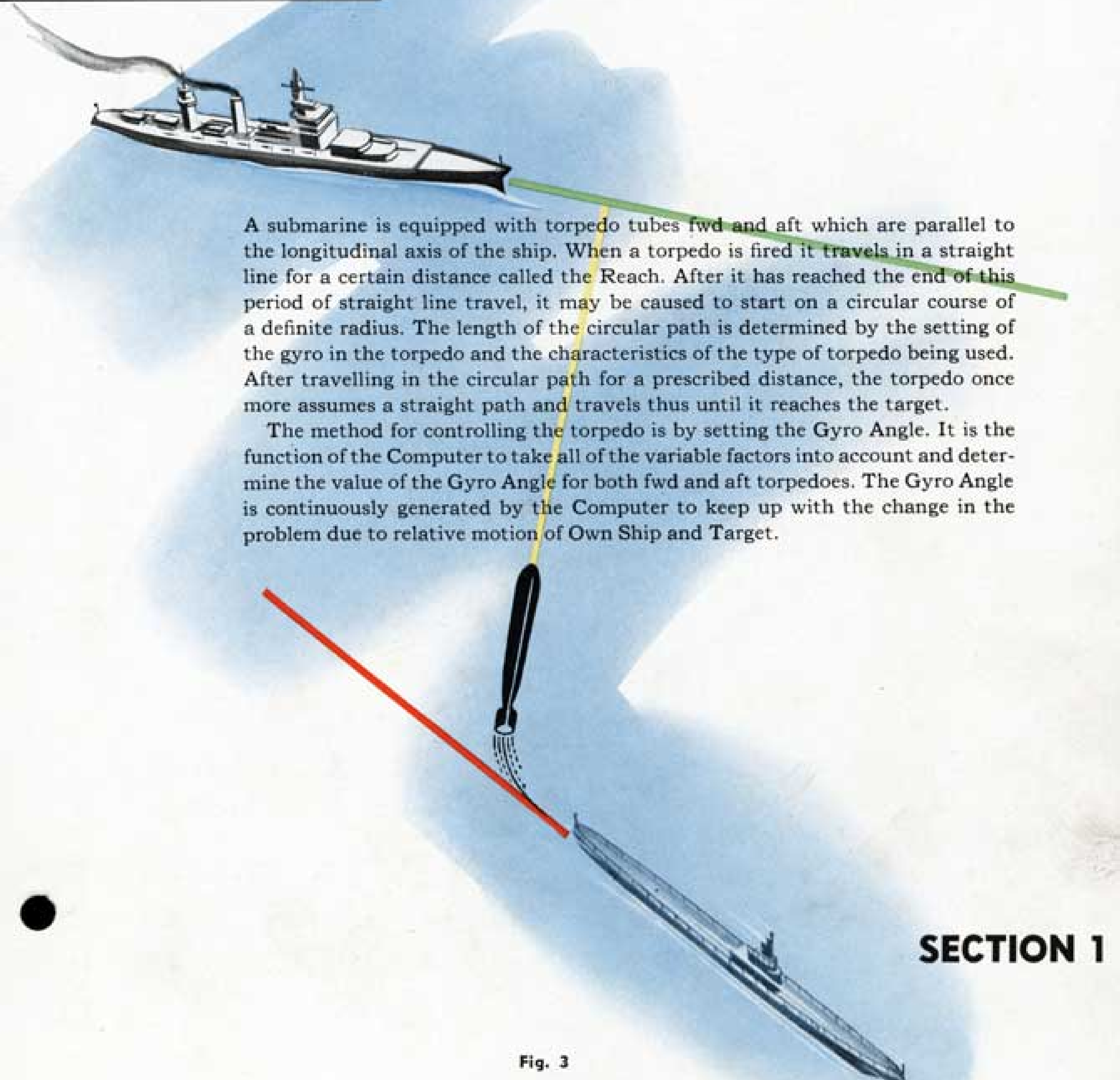
MK. 3 MOD. 9

This page is blank.

ANALYSIS OF FIRE CONTROL PROBLEM

A submarine is equipped with torpedo tubes fwd and aft which are parallel to the longitudinal axis of the ship. When a torpedo is fired it travels in a straight line for a certain distance called the Reach. After it has reached the end of this period of straight line travel, it may be caused to start on a circular course of a definite radius. The length of the circular path is determined by the setting of the gyro in the torpedo and the characteristics of the type of torpedo being used. After travelling in the circular path for a prescribed distance, the torpedo once more assumes a straight path and travels thus until it reaches the target.

The method for controlling the torpedo is by setting the Gyro Angle. It is the function of the Computer to take all of the variable factors into account and determine the value of the Gyro Angle for both fwd and aft torpedoes. The Gyro Angle is continuously generated by the Computer to keep up with the change in the problem due to relative motion of Own Ship and Target.



SECTION 1

Fig. 3

DISTANCES

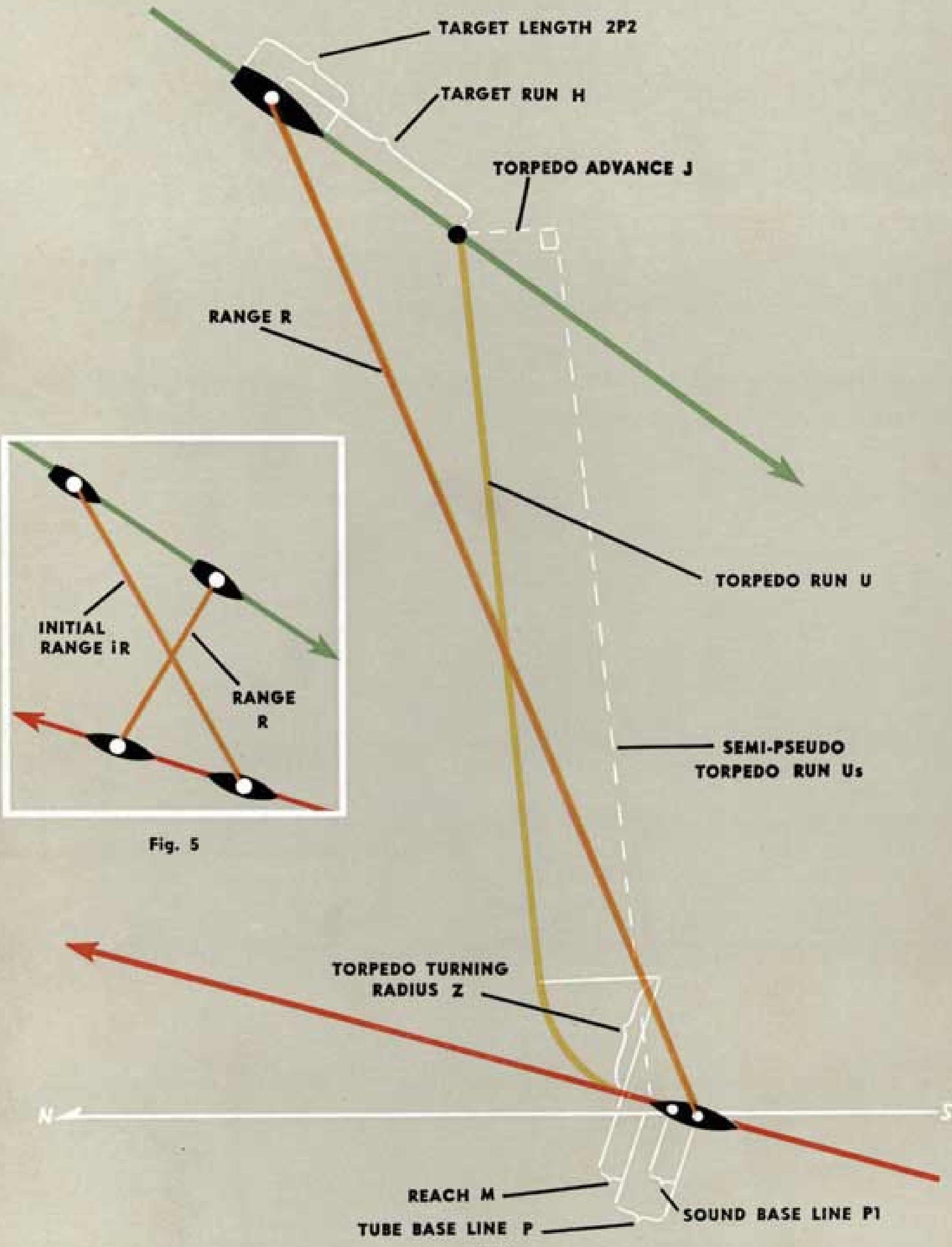


Fig. 5

Fig. 4

TERMINOLOGY SYMBOLS

DISTANCES

H	Target Run—The distance in yards traveled by the Target during the time of actual torpedo run.
M	Reach—The initial straight path of the torpedo in yards.
Z	Torpedo Turning Radius—The radius of the circular torpedo path from the end of the initial straight path to the beginning of the final straight path in yards.
U	Torpedo Run—The distance in yards which the torpedo actually travels along its path from the end of the tube to the point of intercept with the target.
Us	Semi-pseudo Torpedo Run—The distance in yards along a line parallel to the final track of the torpedo, measured from the torpedo tube to a point abreast of the point of impact.
J	Torpedo Advance—The perpendicular distance in yards between the final track of the torpedo and the line from the torpedo tube muzzle parallel to this final track.
P	Tube Base Line—The distance in yards between the conning tower periscope position and the torpedo tube. This distance varies for fwd and aft torpedo tubes.
P1	Sound Base Line—The distance in feet between the conning tower periscope and the sound receiver.
2P2	Target Length—The length of the Target in feet.
R	Range—The distance in yards from the periscope to the Target at the present instant.
iR	Initial Range—Range at the initial instant.
$\triangle$R	The total change in Range over a finite period of time. Fig. 13, Page 22.
$\frac{3SR}{2889}$	Target travel during time of sound travel in feet. Fig. 9, Page 16.
$\frac{SR}{1000}$	Function of 3SR/2889 as calibrated on index plate of instrument.
Uy	Torpedo Run Difference—The Torpedo Run for a given time minus the distance the torpedo would have traveled during the same time at Corrected Torpedo Running Speed, in yards.
Ug	For a given Gyro Angle the difference between the Actual and Semi-pseudo Torpedo Runs (U—Us) in yards.

ANGLES

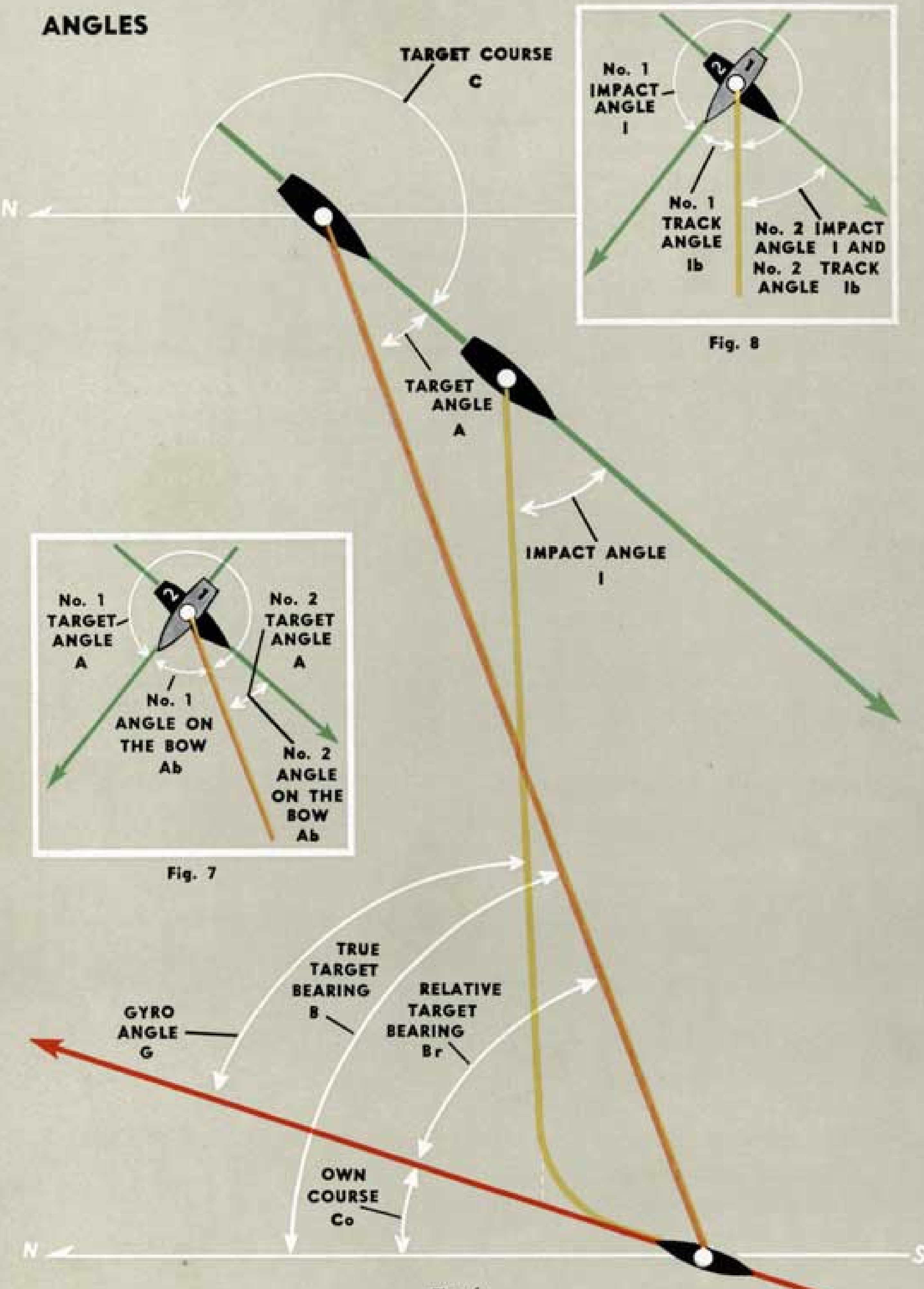


Fig. 8

Fig. 7

Fig. 6

SPEEDS

S	Target Speed—The speed of the Target in knots.
So	Own Speed—The speed of Own Ship in knots.
Sy	Depth Running Speed Correction—The correction in knots to be added to Torpedo Running Speed due to running at depths other than that at which it was proved.
Sz	Torpedo Running Speed—The uniform running speed in knots at proof depth.
S'z	Corrected Torpedo Speed—The uniform running speed in knots at depths other than proof depth.

TIME

Ta	The time in seconds of torpedo travel at proof depth.
T'a	Corrected time of Torpedo Run—The time in seconds of torpedo travel when running at other than proof depth.

ANGLES

A	Target Angle—The angle between the fwd and aft axis of the Target and the Line of Sight to the Target, measured clockwise from the Target bow (0° to 360°).
Ab	Angle on the Bow—The angle between the fwd and aft axis of the Target and the Line of Sight to the Target, measured from the Target bow to starboard or port (0° to ± 180°).
B	True Target Bearing—The angle between the North and South line and the Line of Sight to the Target, measured clockwise from North (0° to 360°).
Br	Relative Target Bearing—The angle between the vertical plane through the fwd and aft axis of Own Ship and the vertical plane through the Line of Sight measured clockwise from the bow (0° to 360°).
C	Target Course—The angle between the North and South line and the fwd and aft axis of the Target, measured clockwise from North to Target bow (0° to 360°).
Co	Own Course—The angle between the North and South line and the fwd and aft axis of Own Ship, measured clockwise from North to Own Ship bow (0° to 360°).
G	Gyro Angle—The angle between the fwd and aft axis of Own Ship and the final track of the torpedo, measured clockwise from Own Ship bow (0° to 360°).
L	Offset Angle—An arbitrary offset to the Gyro Angle.
G'	Corrected Gyro Angle (G+L)—Gyro Angle corrected for Offset Angle.
I	Impact Angle—The angle between the fwd and aft axis of the Target and the reverse track of the torpedo, measured clockwise from the Target bow (0° to 360°).
Ib	Track Angle—The angle between the fwd and aft axis of the Target and the reverse track of the torpedo, measured starboard and port from the Target bow (0° to ± 180°).

ANGLES

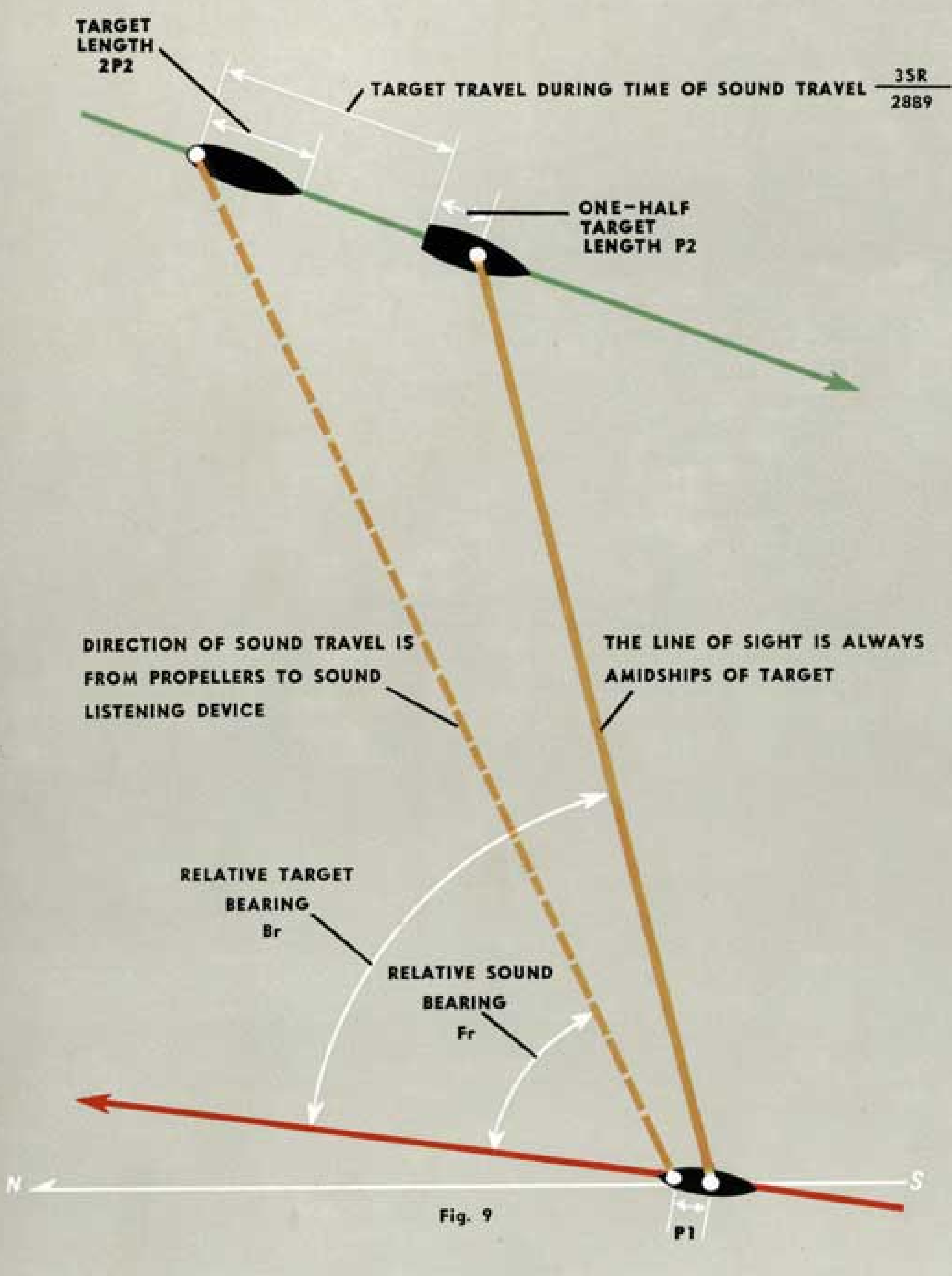

TARGET
LENGTH
2P2
TARGET TRAVEL DURING TIME OF SOUND TRAVEL $\frac{3SR}{2889}$
ONE-HALF
TARGET
LENGTH P2
DIRECTION OF SOUND TRAVEL IS
FROM PROPELLERS TO SOUND
LISTENING DEVICE
THE LINE OF SIGHT IS ALWAYS
AMIDSHIPS OF TARGET
RELATIVE TARGET
BEARING
Br
RELATIVE SOUND
BEARING
Fr
N
S
P1

Fig. 9

TERMINOLOGY AND SYMBOLS

ANGLES

iA	Initial Target Angle—The Target angle at the initial instant (0° to 360°).
iB	Initial True Target Bearing—The initial angle between the North and South line and the Line of Sight to the Target, measured clockwise from North (0° to 360°).
△B	Change of True Target Bearing.
iBr	Initial Relative Target Bearing—The initial angle between the fwd and aft axis of Own Ship and the Line of Sight to the Target, measured clockwise from Own Ship bow (0° to 360°).
Fr	Relative Sound Bearing—The angle between the fwd and aft axis of Own Ship and the direction of sound travel, measured clockwise from Own Ship bow (0° to 360°).

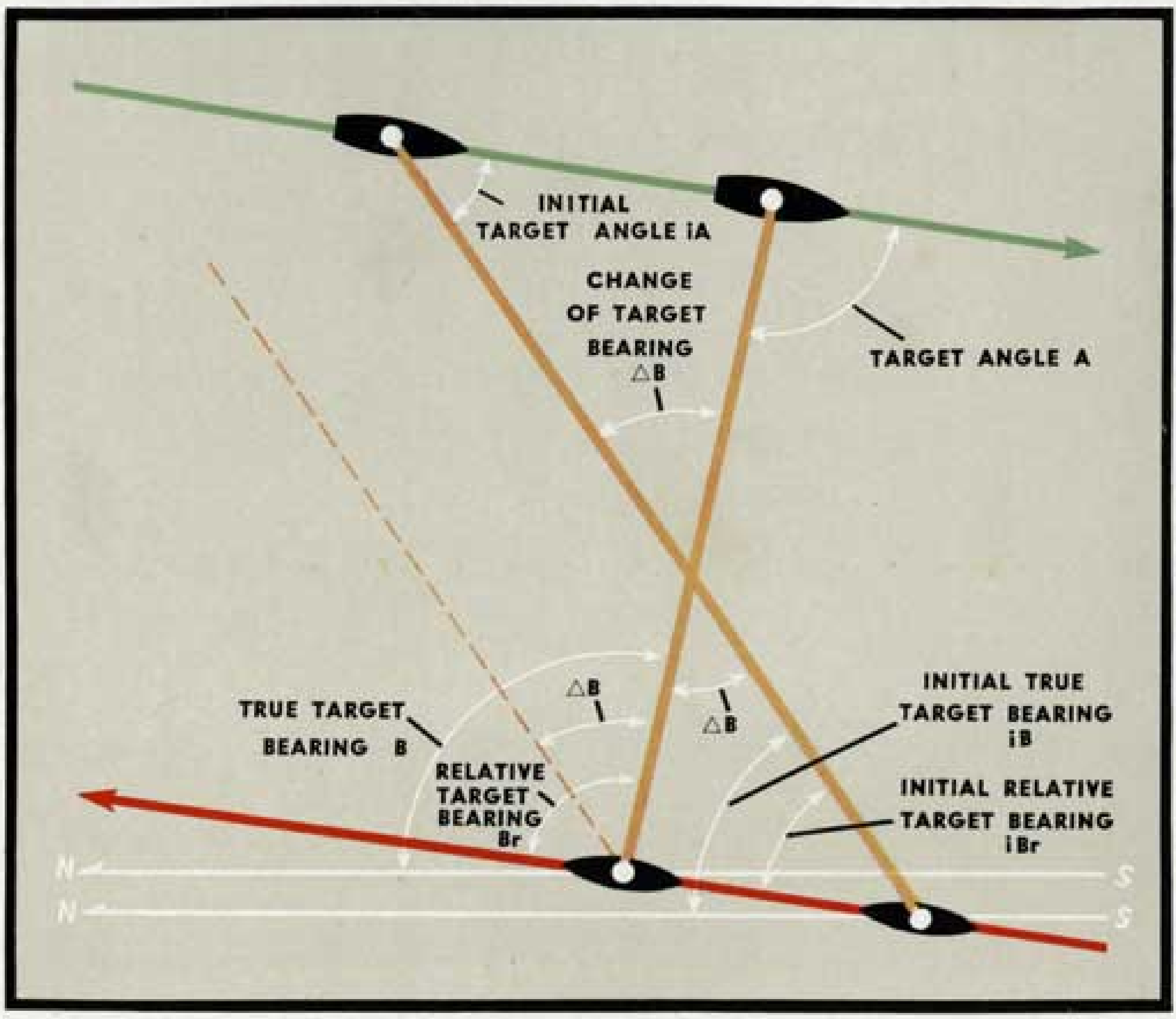


Fig. 10

REVIEW OF TRIGONOMETRY

The trigonometry necessary for the derivation of the equations solved by the Torpedo Data Computor requires a study of triangles and uses several terms which will be defined.

In a right triangle as in Fig. 11, there are two acute angles and one 90° or right angle.

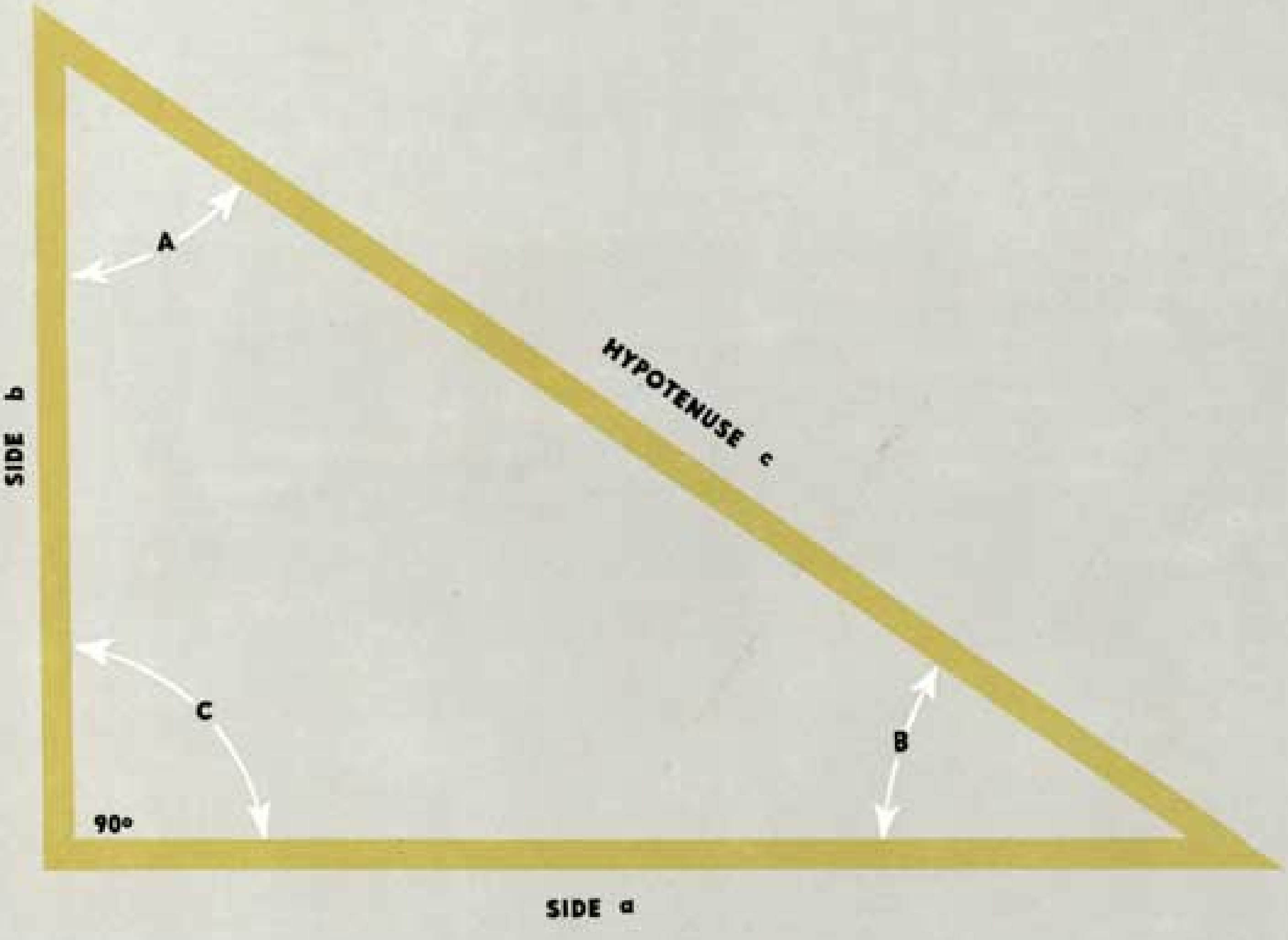


Fig. 11

The angles are lettered A, B, and C, angle C being the right angle. The sides opposite the angles have small letters corresponding to the letters of the angles.

The sine of angle A, or merely sin A, is defined as a ratio, being equal to the opposite side divided by the hypotenuse or,

$$\sin A = \frac{a}{c} \qquad \text{I}$$

The cosine of angle A, or cos A, is defined as equal to the adjacent side divided by the hypotenuse or,

$$\cos A = \frac{b}{c} \qquad \text{II}$$

also by the same analysis

$$\sin B = \frac{b}{c} \qquad \text{III}$$

$$\cos B = \frac{a}{c} \qquad \text{IV}$$

therefore,

$$\sin A = \cos B = \frac{a}{c} \qquad \text{V}$$

The sum of the three angles of any triangle equals 180°.
Therefore in the right triangle

$$A + B = 90^\circ \text{ or } B = 90^\circ - A \qquad \text{VI}$$

and from V and VI

$$\sin A = \cos\,(90^\circ - A) \qquad \text{VII}$$

The tangent of angle A, or tan A, is defined as equal to the opposite side divided by the adjacent side or,

$$\tan A = \frac{a}{b} \qquad \text{VIII}$$

also,

$$\tan B = \frac{b}{a} \qquad \text{IX}$$

> The sine of an angle increases from 0 to 1 as the angle increases from 0° to 90°. The cosine of an angle decreases from 1 to 0 as the angle increases from 0° to 90°. The tangent of an angle increases from zero as the angle increases from zero, and becomes infinitely great as the angle approaches 90°.

GENERAL PROBLEM

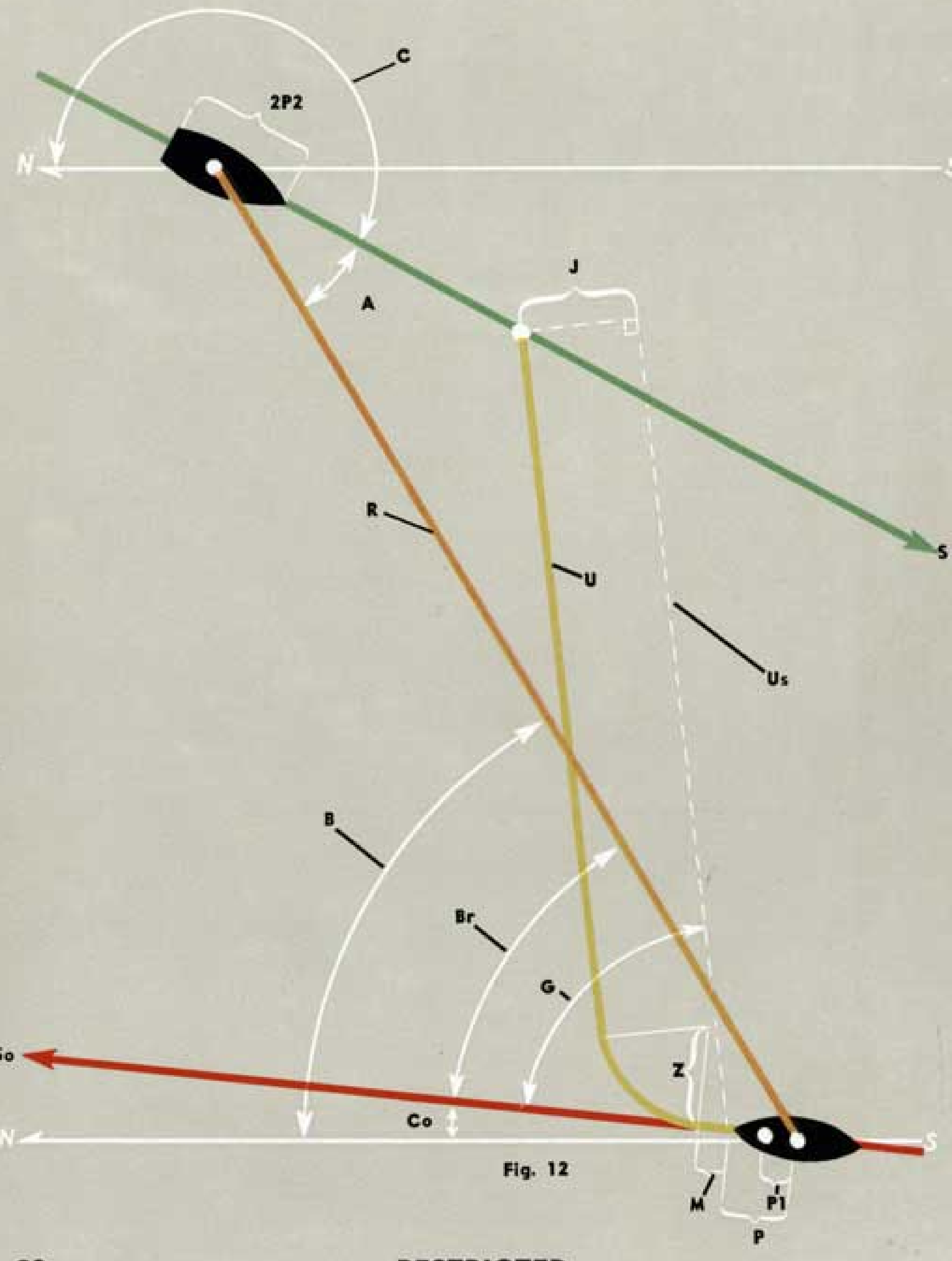


Fig. 12

DERIVATION OF EQUATIONS

GENERAL PROBLEM

The general problem solved by the Torpedo Data Computer is illustrated in Fig. 12. The principal parts of the Torpedo Data Computer are: the Position Keeper, the Sound Bearing Converter, and the fwd and aft Angle Solvers.

The Position Keeper receives values of Own Speed, So, Own Course, Co, Target Speed, S, Target Course, C, True Target Bearing, B, and Range, R. In conjunction with a Time Motor, the instrument will continue to produce values indicating the position of the Target by generating values of Relative Target Bearing and Range as Own Ship and Target move. Target Angle is also generated for use by the Angle Solver and the Sound Bearing Converter.

The Sound Bearing Converter is associated with the Position Keeper and receives a value of Target travel during time of sound travel, plus one-half Target length, as well as continuously maintained values of Target Angle, Relative Target Bearing and Range. A value of Br—Fr is continuously generated. This is converted to Relative Sound Bearing and is continuously indicated on the dials of the Position Keeper.

The Angle Solver receives a value of Target Speed as well as continuously maintained values of Relative Target Bearing, Target Angle and Range from the Position Keeper. Values pertaining to the characteristics of the particular torpedo being used are introduced into the instrument manually. The Angle Solver then produces a value of Gyro Angle and continues to maintain the correct value of Gyro Angle so that a torpedo fired from a submarine will reach a point on the track of the Target at the same time the Target reaches that point.

On the following pages are derived the equations solved by the Position Keeper and the Angle Solver and also the equations solved by the associated Sound Bearing Converter.

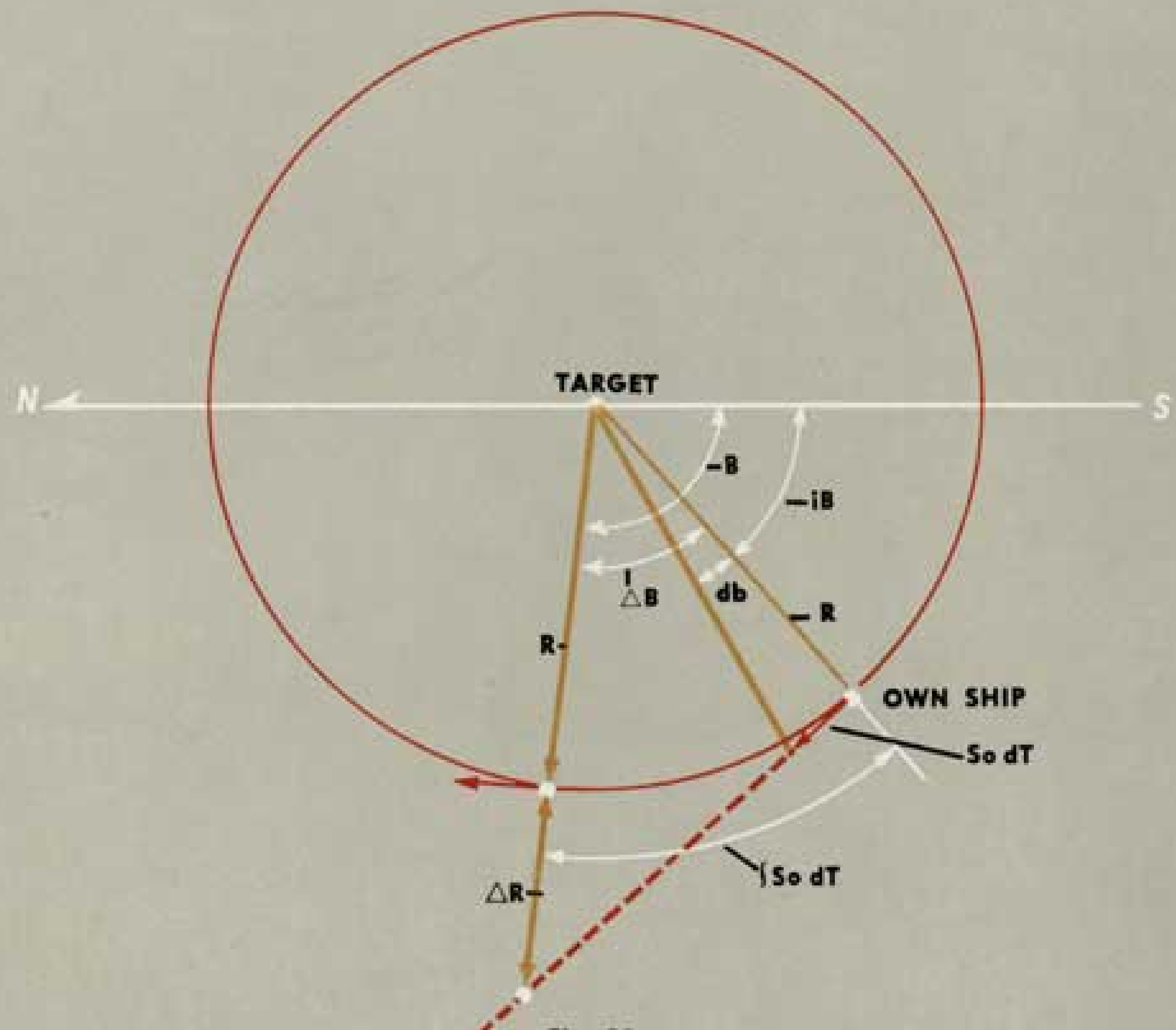


Fig. 13

DERIVATION OF EQUATIONS SOLVED BY THE POSITION KEEPER

In considering the motion of a ship, the concept of infinitesimal time must be used. An infinitesimal period of time is defined as an amount of time smaller than any assignable value. It is the duration of an instant.

If a ship accelerates while traveling on a straight course, that is, changes speed, at each instant it will have a definite assignable speed. For instance, if a ship accelerated uniformly from a speed of 10 knots to a speed of 20 knots in a period of 2 minutes, at the end of the first minute its speed at that instant would be 15 knots.

The distance that the ship will travel during any given instant will be the product

of the speed of the ship at that instant multiplied by the duration of that instant and is written So dT where dT denotes an infinitesimal period of time.

If all these instantaneous distances are added together, the result will be the total distance traveled by the ship during the finite period of time under consideration. If the ship were traveling at a constant speed the total distance traveled would be the speed multiplied by the total time. However, if the speed of the ship varies during this time, the total distance traveled during a finite period of time can only be written as the summation of all the instantaneous products of the instantaneous speeds multiplied by the duration of the instants that they existed, or $\int So\,dT$, where the elongated S-shaped character indicates that the summation of the instantaneous products is to be performed. If a Target were stationary and Own Ship were traveling along the line of sight, the instantaneous distances traveled would be the instantaneous changes in Range $dR = So\,dT$ and over a given period of time, the total change in Range would be $\triangle R = \int So\,dT$ where the symbol $\triangle$ denotes the total change.

Fig. 13, illustrates a situation where the Target is stationary and at the center of a circular course that is being traversed by Own Ship. The instantaneous travel of Own Ship will again be $So\,dT$. Here, due to the instantaneous motion of Own Ship, there will also be an instantaneous change in True Target Bearing denoted by dB. From the exaggerated figure it can be seen that $R \tan dB = So\,dT$

The tangent of a very small angle is very nearly equal numerically to the angle itself when the angle is measured in radians. For an infinitesimal angle, the tangent is exactly equal numerically to the angle itself. Therefore, instantaneously $R\,dB = So\,dT$

As the ship moves in the circular path, it is constantly moving across the Line of Sight and never along the Line of Sight. Hence there is no change in Range. The total change in True Target Bearing is $\triangle B = 1/R \int So\,dT$

This expression is only true when the ship is traveling in the circular path. If for instance, Own Ship traveled along the straight path indicated by the dotted line, in Fig. 13, the change in True Target Bearing would depend only upon the component of the motion of Own Ship across the Line of Sight, and further it must be agreed that for each instantaneous change in True Target Bearing, the value of Range shall be used which corresponds to that instantaneous True Target Bearing.

The instantaneous change in Range, dR, in this case would only be dependent upon that component of the motion of Own Ship which is along the Line of Sight.

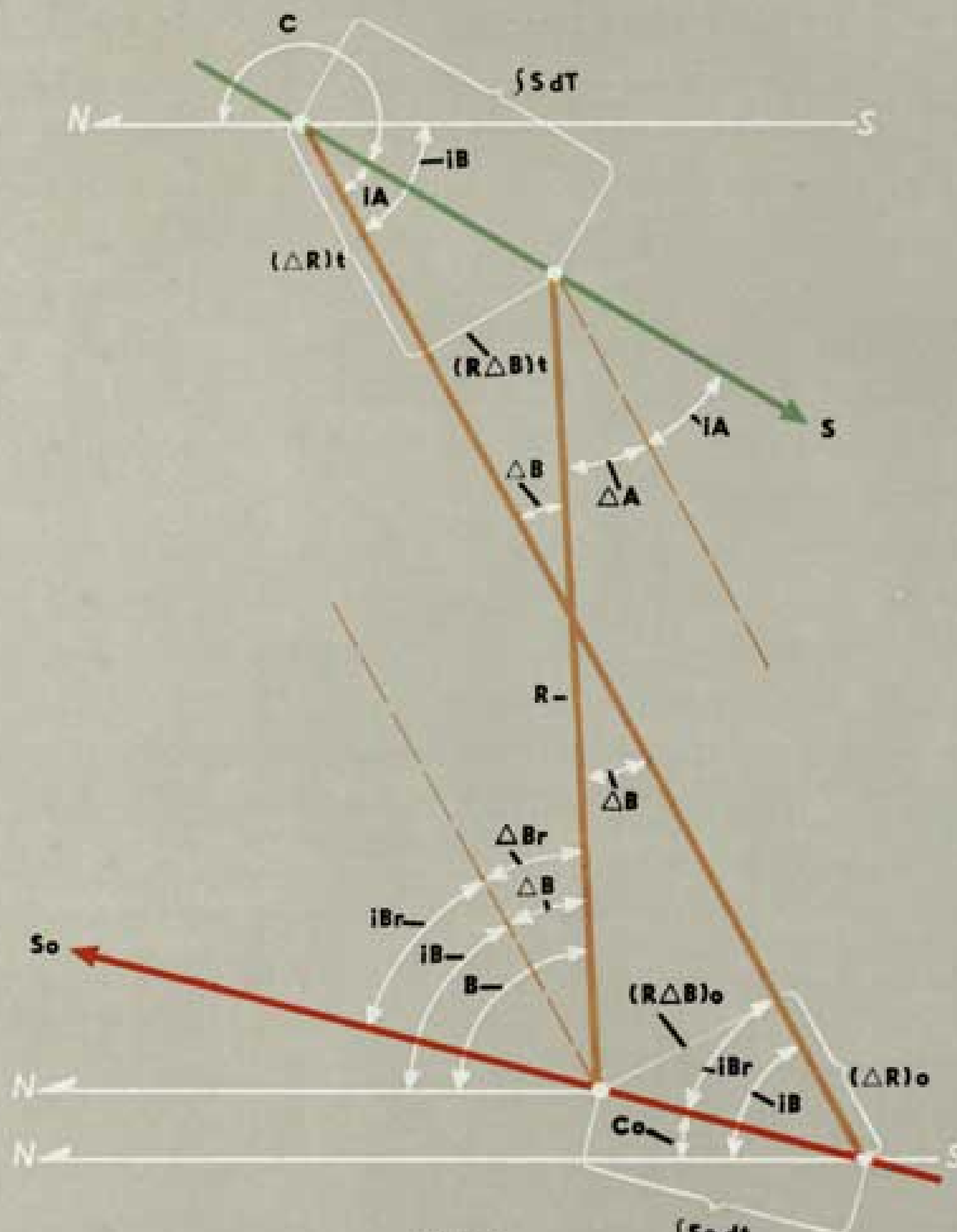


Fig. 14

Fig. 14, illustrates a situation where both Target and Own Ship are moving on straight courses. The figure, of necessity, shows total changes along and across the Line of Sight due to motion of Own Ship, and total changes along and across the Line of Sight due to motion of the Target, which are erroneous as will be seen later, since it is impossible to depict infinitesimal distances.

At each instant, the motion of Own Ship across the Line of Sight will be equal to the instantaneous distance it traveled along its course multiplied by the sine of the Relative Target Bearing Angle that existed at that instant, or

$$(R\,dB)o = So\,dT \sin Br \qquad \text{I}$$

Similarly, at each instant, the motion of the Target across the Line of Sight will equal its instantaneous motion along its course multiplied by the sine of the Target Angle that existed at that instant.

Hence

$$(R\,dB)t = S\,dT \sin A \qquad \text{II}$$

The total instantaneous change across the Line of Sight will be the sum of the change due to Own Ship and the change due to Target motion.
Therefore,

$$R\,dB = (R\,dB)o + (R\,dB)t = So\,dT \sin Br + S\,dT \sin A \qquad \text{III}$$

Over a finite period of time

$$R\triangle B = \int So\,dT \sin Br + \int S\,dT \sin A^{*} \qquad \text{IV}$$

The instantaneous change along the Line of Sight due to the motion of Own Ship will be the instantaneous motion of the ship along its course multiplied by the cosine of the Relative Target Bearing Angle that existed at that instant.

$$(dR)o = So\,dT \cos Br \qquad \text{V}$$

Similarly the instantaneous change along the Line of Sight due to Target motion will be the instantaneous motion of the Target along its course multiplied by the cosine of the Target Angle that existed at that instant.

$$(dR)t = S\,dT \cos A \qquad \text{VI}$$

Hence, the total instantaneous change along the Line of Sight, that is, the total instantaneous change in Range, is

$$dR = (dR)o + (dR)t = So\,dT \cos Br + S\,dT \cos A \qquad \text{VII}$$

or over a finite period

$$\triangle R = \int So\,dT \cos Br + \int S\,dT \cos A \qquad \text{VIII}$$

The instantaneous change in True Target Bearing may be obtained from equation III. This equation may be rewritten

$$dB = 1/R(So\,dT \sin Br + S\,dT \sin A)^{*} \qquad \text{IX}$$

or over a finite period

$$\triangle B = 1/R\left(\int So\,dT \sin Br + \int S\,dT \sin A\right)^{*} \qquad \text{X}$$

The ratio indicated by the right hand side of this equation is actually the tangent of the instantaneous change in True Target Bearing. Again, however, since dB is the instantaneous change in True Target Bearing, the tangent of the angle is numerically equal to the angle itself if the angle is measured in radians. This is only true for the instantaneous values of dB, and the instantaneously existing value of R must be used.

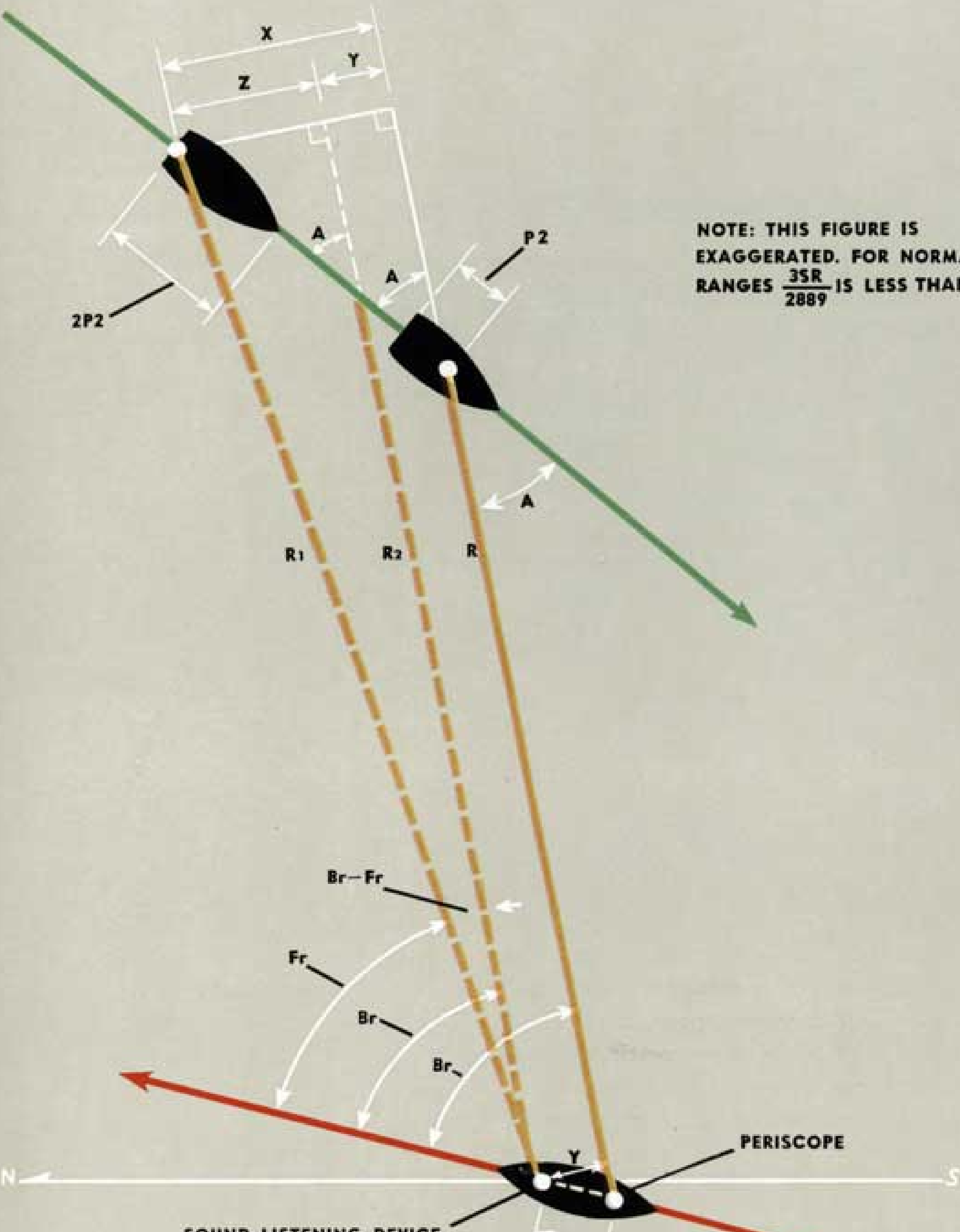
From Fig. 14 the initial Range minus the sum of the changes in Range indicated does not equal the final Range indicated, as may be found by scaling the figure. This is due to the fact that the total change in Range, $\triangle R$, is the sum of instantaneous products wherein each successive product involved a trigonometric value less than the preceding one. Hence the total change in Range is less than it would have been if the trigonometric values of the initial angles had been used in each instantaneous product as is erroneously depicted in the figure. The total change across the Line of Sight is similarly erroneously indicated.

The other equations solved by the Position Keeper are illustrated in Fig. 14,

$$iBr = iB - Co \text{ and } iA = iB + 180^{\circ} - C$$

*These equations are true only if it is agreed that each value of R that is used with each instantaneous product corresponds to the particular dB at that instant.

SOUND BEARING PROBLEM



NOTE: THIS FIGURE IS EXAGGERATED. FOR NORMAL RANGES $\frac{3SR}{2889}$ IS LESS THAN P2

Fig. 15

or at any subsequent time

$$Br = B - Co \qquad \text{XI}$$

and

$$A = B + 180° - C \qquad \text{XII}$$

Equations I through IX are continuously solved by the Position Keeper, and the instantaneous products are continuously added together producing the total changes. Further, the Position Keeper continuously adheres to the condition necessary for the validity of Equation IX.

DERIVATION OF EQUATIONS SOLVED BY THE SOUND BEARING CONVERTER

The Sound Bearing problem is shown in Fig. 15. The Target is shown in two positions, first when the sound leaves the Target and next when the sound reaches the sound receiver of Own Ship.

Since the speed of sound in salt water is 2889 knots, the time of sound travel is proportional to R1/2889. If the Target Speed is S, the Target will move SR1/2889 yards or 3SR1/2889 feet during the time that the sound travels from the Target to Own Ship. Due to the fact that the speed of sound is many times greater than the Target Speed, there is a negligible error in assuming R1 equal to R. Therefore, the Target travel may be written 3SR/2889.

From Fig. 15, since the sound started from the propellers while the Line of Sight is amidships, sin A equals X divided by the sum of Target travel and half the Target Length.

$$\sin A = \frac{X}{P2 + \frac{3SR}{2889}}$$

or,

$$X = \left(P2 + \frac{3SR}{2889}\right) \sin A \text{ in feet} \qquad \text{XIII}$$

Also from Fig. 15, Page 26, sin Br equals Y divided by the Sound Base Line, Pl. Therefore, we have

$$\sin Br = \frac{Y}{P1}$$

or,

$$Y = P1 \sin Br \text{ in feet} \qquad \text{XIV}$$

It can further be seen that $Z = R2 \tan (Br - Fr)$ in yards

Again, since the speed of sound in water is considerably greater than the Target Speed, R2 and R may be assumed equal.

$$Z = R \tan (Br - Fr) \text{ in yards}$$
$$= 3R \tan (Br - Fr) \text{ in feet}$$

Now, since

$$X - Y = Z$$

$$\left(P2 + \frac{3SR}{2889}\right) \sin A - P1 \sin Br = 3R \tan (Br - Fr) \qquad \text{XV}$$

Then

$$Br - Fr = \tan^{-1}\left[\left(\frac{3R}{3R} \tan (Br - Fr)\right]\right. \qquad \text{XVI}$$

ANGLE SOLVER PROBLEM

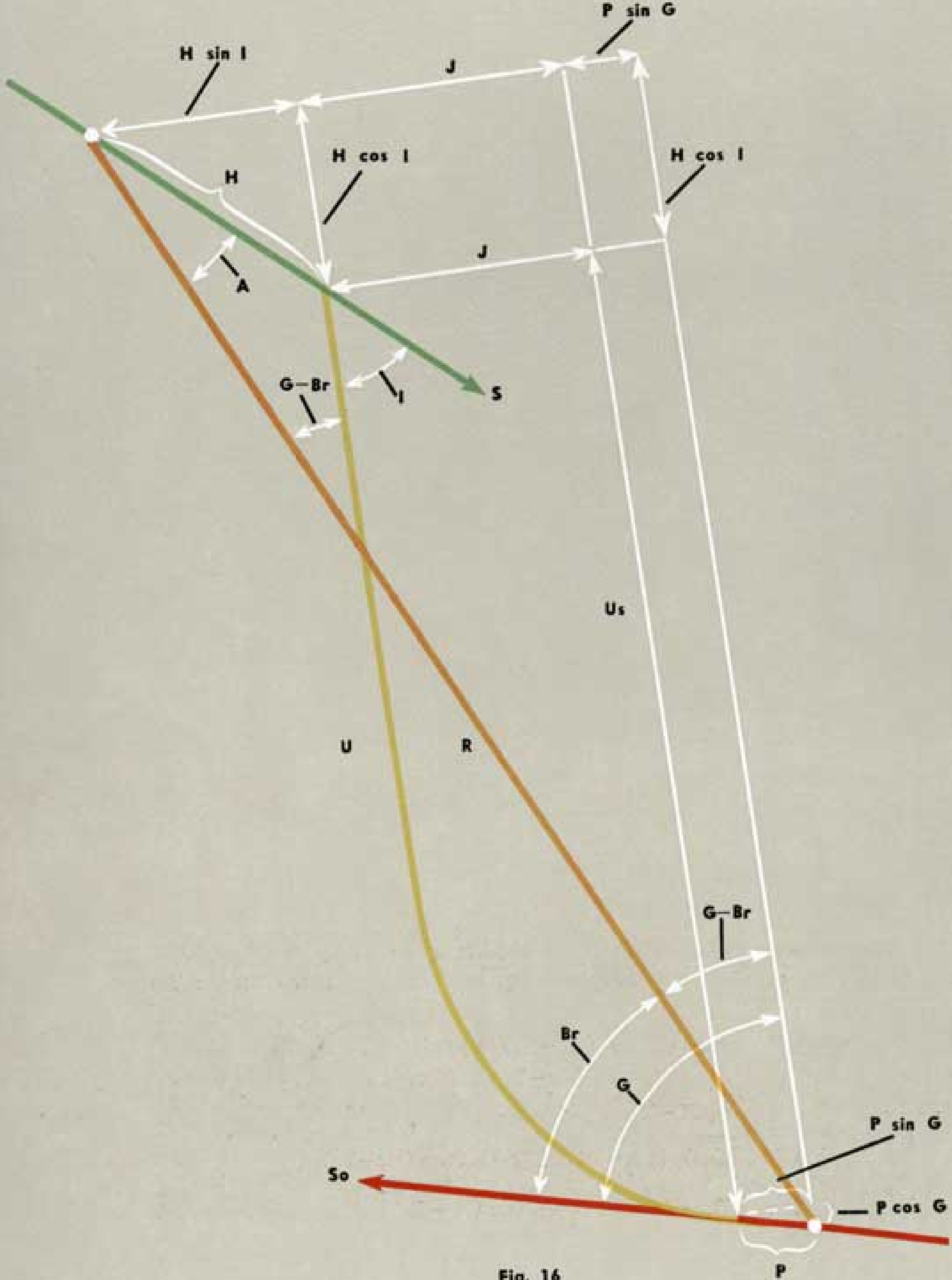


Fig. 16

DERIVATION OF EQUATIONS SOLVED BY THE ANGLE SOLVER

Fig. 16 shows the torpedo fire control problem based upon the given values of R, Br, S, and A. From this figure the following equations can be derived:

$$R\cos(G-Br)-H\cos I=Us+P\cos G \qquad \text{XVII}$$

$$R\sin(G-Br)-H\sin I=J+P\sin G \qquad \text{XVIII}$$

$$I=A+(G-Br) \qquad \text{XIX}$$

For any torpedo the tactical data is based on the following equation:

(a) For straight shots beyond 300 yards at standard depth.

$U=(0.563 \times Sz \times Ta)+Uy$,

where

U = Torpedo Travel in yards
0.563 = Factor used to convert speed in knots to yards per second.
Sz = Running Speed in knots
Ta = Time of Torpedo Travel in seconds at proof depth
Uy = Torpedo Run Difference in yards

(b) The running speed of the torpedo is the same on curved shots as on straight shots.

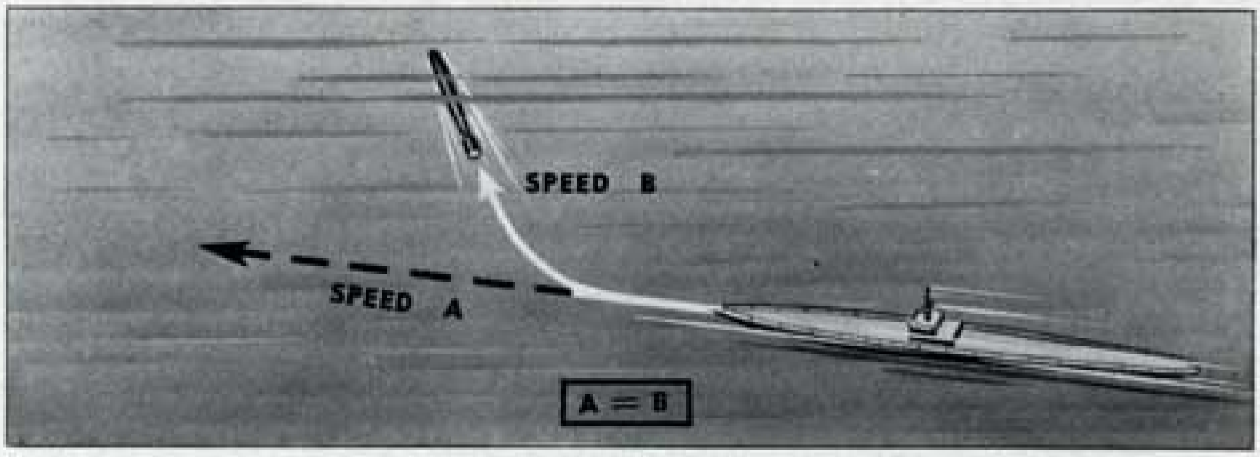


Fig. 17

ANGLE SOLVER GEOMETRY

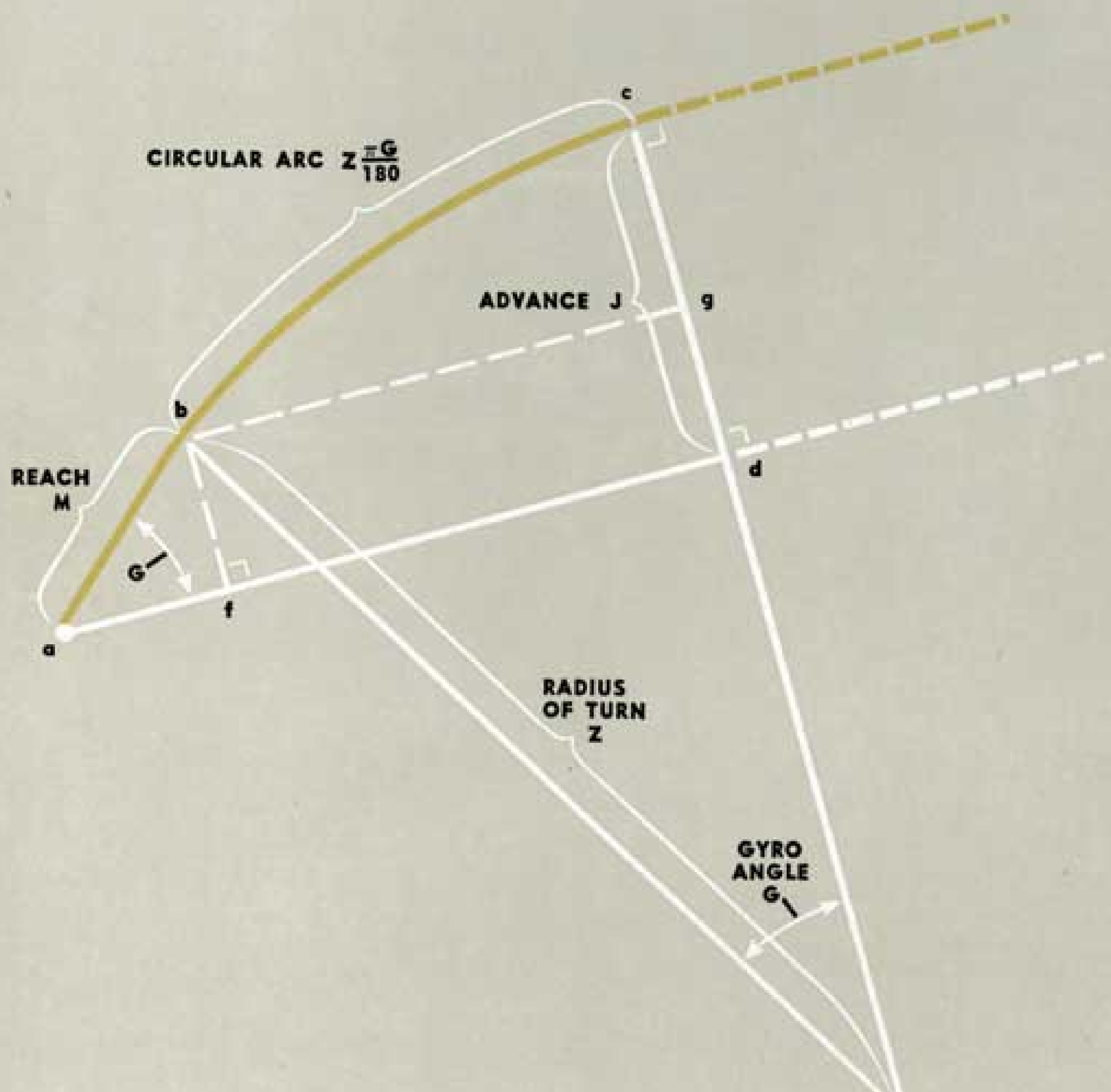


Fig. 18

In Fig. 18 are illustrated the Reach, M, Turning Radius, Z, Advance, J, and the Gyro Angle, G, through which the torpedo turns before traveling in its final straight line.

From the figure:

(a) $dg = fb = M \sin G$

Also

(b) $gc = ec - eg = Z - Z \cos G = Z(1 - \cos G)$

Now $J = dg + gc$

Or, from (a) and (b), $J = M \sin G + Z(1 - \cos G)$ XX

Hence for a given torpedo, the Advance, J, depends solely on the Gyro Angle.

Similarly

(c) $ad = af + fd = af + bg = M \cos G + Z \sin G$

Also arc $bc = ZG$ where G is measured in radians

(d) $= Z\frac{\pi}{180}G$ where G is measured in degrees

Now since the respective parts of U and Us are equal after the torpedo starts on its final straight run, as can be seen from Fig. 4, Page 12,

$$Ug = U - Us = ab + \text{arc } bc - ad$$

Or from (c) and (d), since $M = ab$

$$Ug = M + Z\frac{\pi G}{180} - (M \cos G + Z \sin G)$$

$$= M(1 - \cos G) + Z(\frac{\pi G}{180} - \sin G) \qquad \text{XXI}$$

Hence for a given torpedo the value of Ug depends solely on the Gyro Angle.

In the basic equation (a) on Page 29, the factor 0.563 is a constant multiplier of Sz and in the Computer is introduced by gearing, hence symbolically the equation may be rewritten:

$$U = Sz\ Ta + Uy$$

or $U - Uy = Sz\ Ta$

and since $U = Us + Ug$

$$Us + Ug - Uy = Sz\ Ta$$

The Time of Torpedo Run at proof depth is then

(e) $$Ta = \frac{Us + Ug - Uy}{Sz}$$

The distance traveled by the torpedo at proof depth is Sz Ta and since at any other depth the distance to the same point is the same

$$Sz\ Ta = S'z\ T'a$$

Substituting this in (e) the Corrected Time of Torpedo Run is then

$$T'a = \frac{Us + Ug - Uy}{S'z}$$

If the Target and torpedo are to arrive at the same point at the same time, one necessary condition is that the Time of Target Run must be the same as the Corrected Time of Torpedo Run.

Therefore

$$T'a = \frac{Us + Ug - Uy}{S'z} = \frac{H}{S} \qquad \text{XXII}$$

If the numerical values of $Us + Ug - Uy$ and $S'z$ are used graphically to represent the sides opposite and adjacent respectively to an angle of a right triangle, that angle must be an angle whose tangent is T'a. Similarly if the numerical values of H and S are also the sides opposite and adjacent to an angle of a right triangle, that angle must also be an angle whose tangent is T'a if the Target and torpedo are to meet.

The foregoing equations solve the fire control problem. Each mathematical process in the solution of these equations may be performed mechanically or electro-mechanically as will be shown in the following discussion on the fundamentals of mechanisms. The function of the Torpedo Data Computer is to solve the problem and, provided that the Target follows a straight course at constant speed, maintain a continuous solution.

FUNDAMENTALS

The Data Computer consists of several distinct types of computing devices which operate together to solve the equations of the fire control problem. These devices are for the most part constructed as individual units. In this chapter are described the underlying principles of their operation.

SECTION 2

DIFFERENTIALS

The most common calculating mechanism in the Computer is the differential, which can perform addition and subtraction.

The bevel gear differential occurs most often and will therefore be considered first.

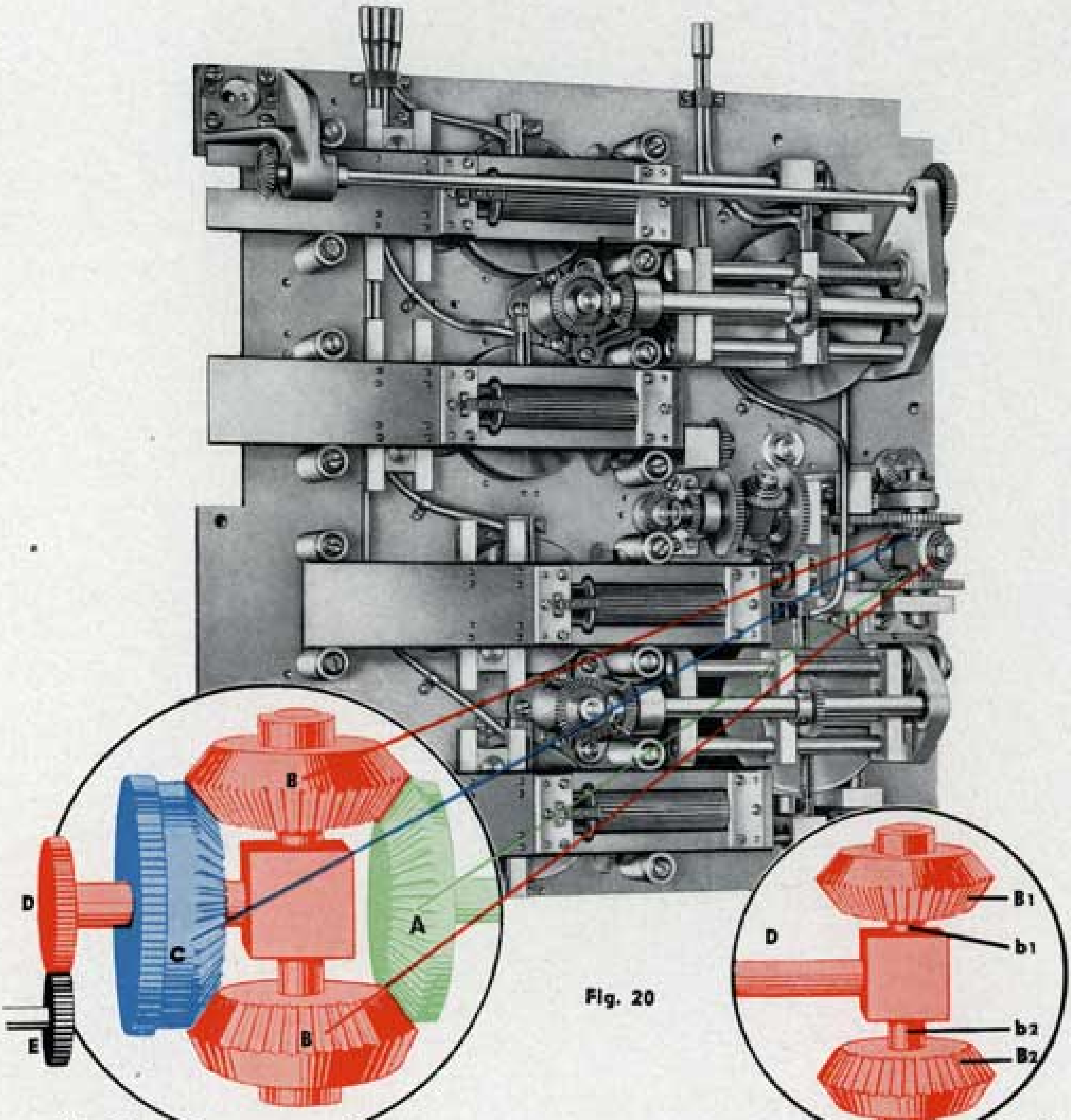


Fig. 19

Fig. 20

Fig. 21

The bevel gear differential is illustrated in Fig. 19. Its components are the large bevel gears, A and C, which supply the input quantities, and the set of spider gears, B, which generate the output quantity and transmit it to shaft D. The spider gears and their shafts are shown in Fig. 21. The two gears B1 and B2 are free to rotate on the shafts b1 and b2, which in turn are rigidly fastened to shaft D.

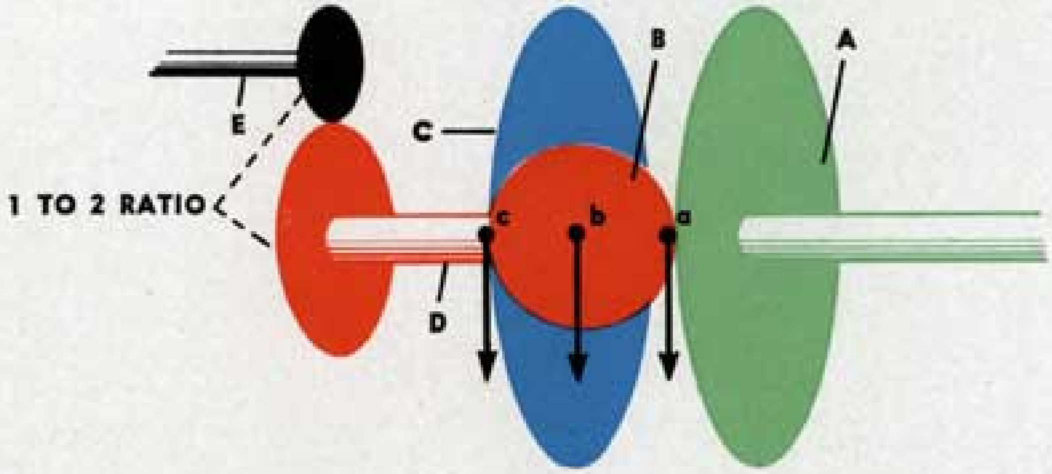


Fig. 22

In Fig. 22, if both driving gears A and C are moving in the same direction at the same speed, the point **a** will remain opposite point **c** as the gears rotate. Therefore, the spider gear B will not rotate on its shaft, but will be carried along with the driving gears causing shaft D to move at the same speed as the gears A and C.

Since the differential is used to add the rotations of the two input gears, it is necessary to double the speed of the output shaft with a set of 2 to 1 gears, which will give the correct rotation to shaft E, that is, two revolutions for one of A plus one of C.

When only one input gear is turning, such as A in Fig. 23, Page 36, shaft E should turn only one revolution for each rotation of A. As gear A moves, the spider gear B rolls on the gear C and its center moves only half as far as the gear A. The shaft E is then rotating at the same speed as A.

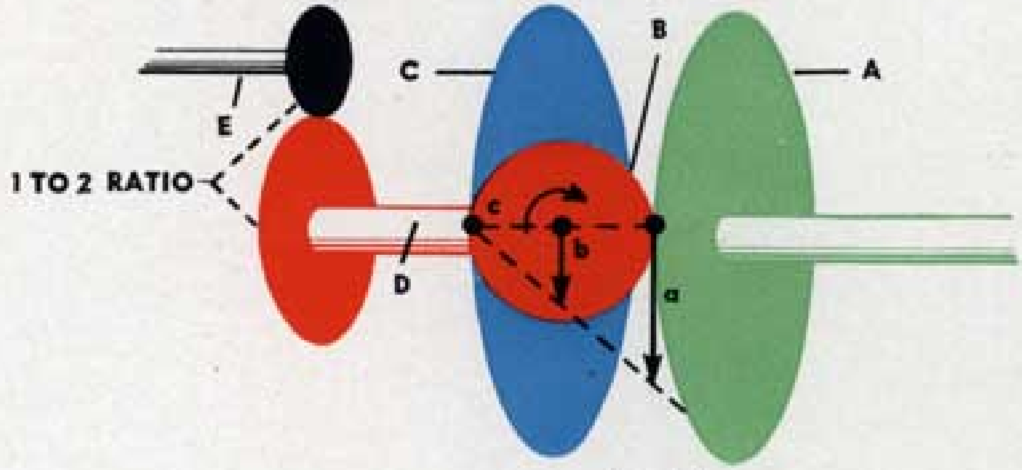


Fig. 23

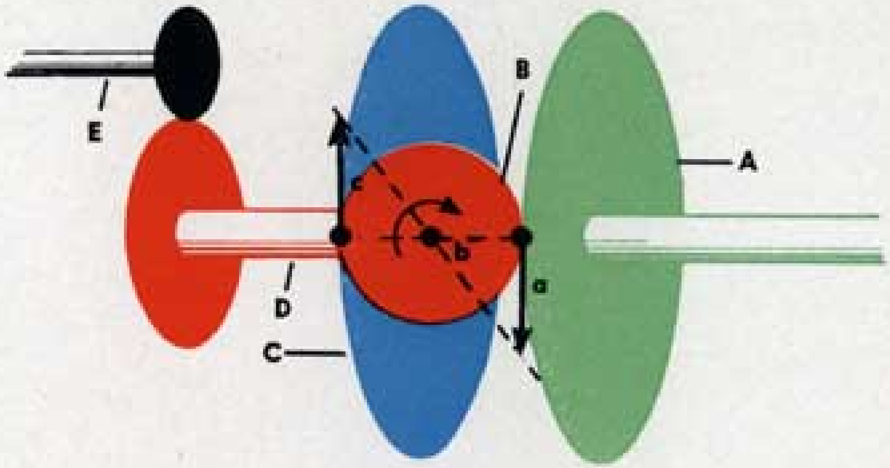


Fig. 24

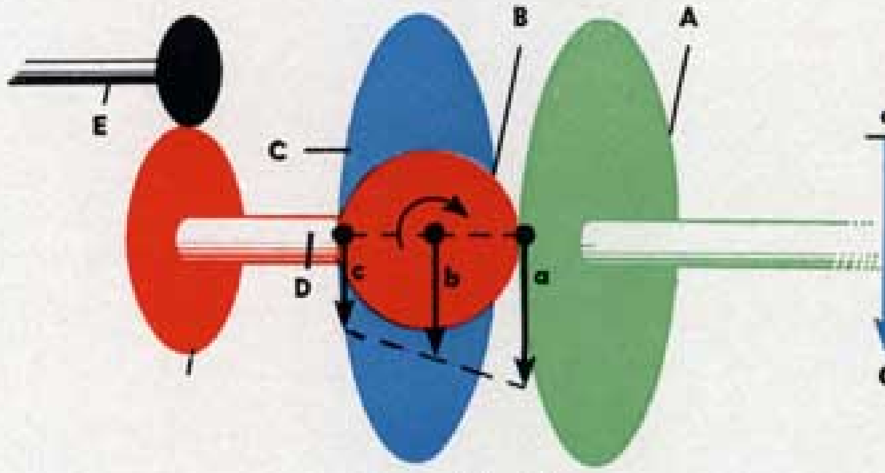


Fig. 25

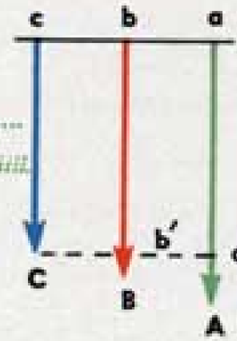


Fig. 25a

If gears A and C move in opposite directions at the same speed, there should be no rotation of shafts D and E since positive and negative quantities of equal magnitude totaling zero are being added. This problem is illustrated in Fig. 24. Connecting the ends of the arrows with a dotted line shows that there is no movement of the center of the spider gear. Therefore, although the spider gear rotates about its own axis, it does not revolve about the axis of shaft D. Hence there is no movement of the shaft D and consequently no movement of the shaft E.

Fig. 25 illustrates the case where the movement consists of unequal rotations of gears A and C in the same direction. Connecting the arrowheads indicates a movement **b** somewhat in between the movements **a** and **c**. In Fig. 25a, the arrow aA is divided into two parts, one of which is aa' equal to the arrow cC. The arrow bB is also divided into two parts bb' and b'B. Due to the movements aa' and cC, the point **b** will move to **b'**. In addition, point **b** will move half of a'A.

Then:

$$bb' = aa' = cC$$

or

$$bb' = \tfrac{1}{2}aa' + \tfrac{1}{2}cC$$

and

$$b'B = \tfrac{1}{2}a'A$$

Therefore,

since

$$bB = bb' + b'B$$

$$bB = \tfrac{1}{2}aa' + \tfrac{1}{2}a'A + \tfrac{1}{2}cC$$

but

$$aa' + a'A = aA$$

Therefore,

$$bB = \tfrac{1}{2}aA + \tfrac{1}{2}cC$$

When bB is doubled to give the movement of shaft E, it results in addition of the movements of gears A and C.

This analysis shows that the mechanism will always give the added motions of the two inputs, and if one of the inputs is in a direction opposite to the other, the result is addition of positive and negative quantities, or subtraction. The 2 to 1 gears and shaft E were added because the spider shaft produces only one half the sum or difference of the two inputs.

By using suitable gearing, it is possible to use any one of the three elements (the two large bevel gears and the set of spider gears) as the output and the other two as inputs.

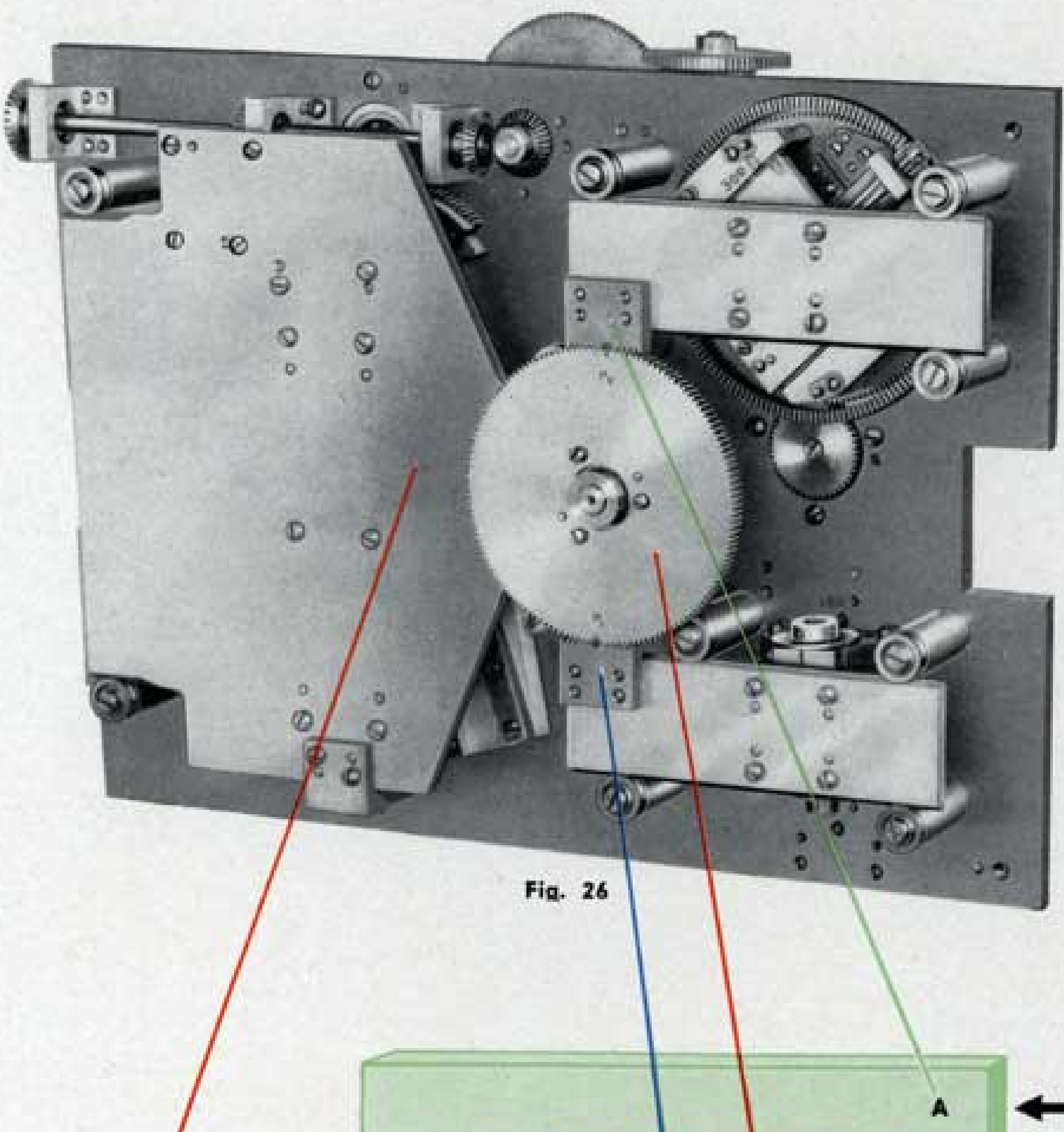


Fig. 26

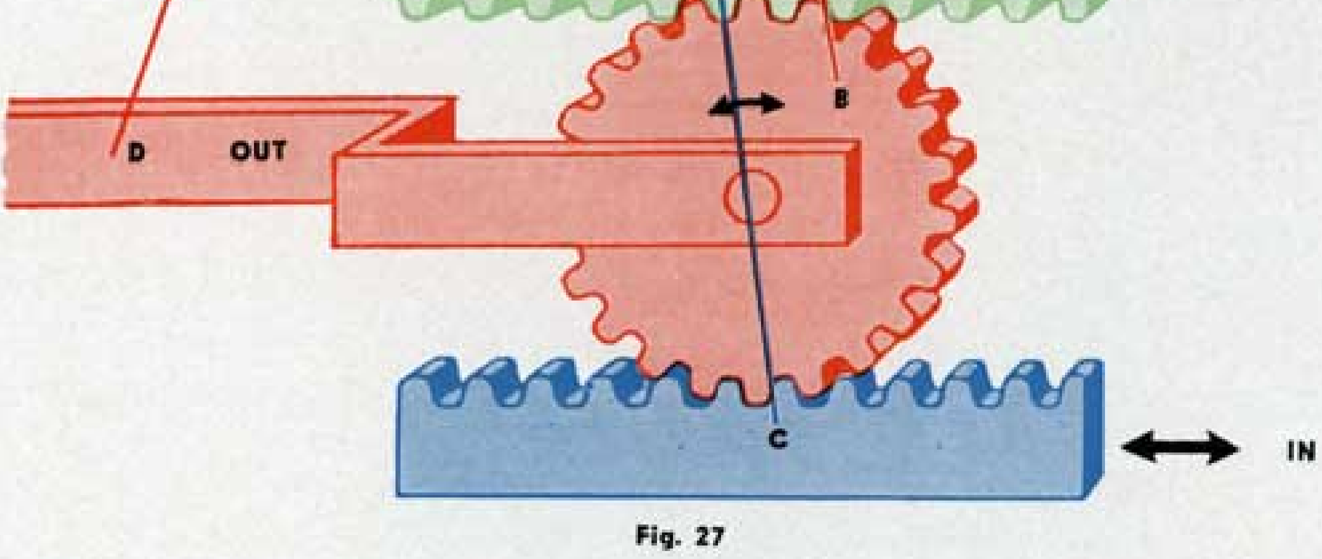


Fig. 27

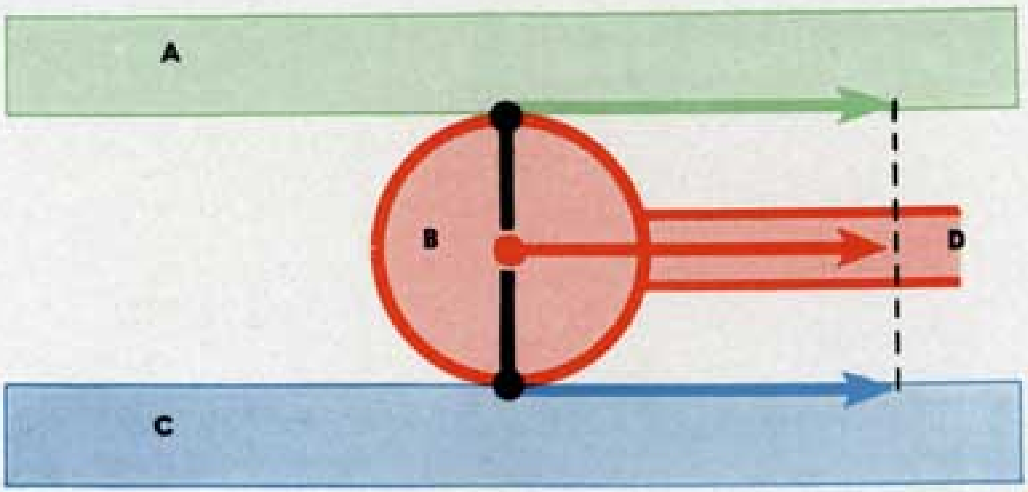


Fig. 28A

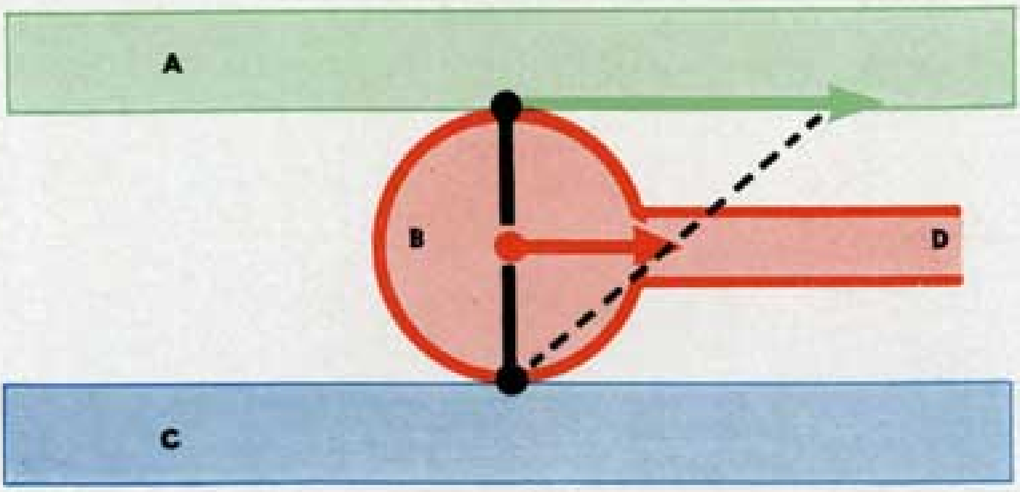


Fig. 28B

Another type of differential which is used is the rack and pinion combination shown in Figs. 26 and 27. In this mechanism the two racks A and C deliver the inputs and the pinion B transfers the output to the carriage D.

The same type of analysis can be made for this device as was made for the bevel gear differential. When both racks move the same distance in the same direction, the pinion will not roll but will be carried along with the two racks as shown in Fig. 28a. In this case the movement of B is half of A plus half of C. The output may be doubled as before.

If in Fig. 28b the rack A moves in the direction and amount shown by the arrow and the rack C remains stationary, the pinion B will roll on the rack C and its center will move half as far as A moved. Therefore, the carriage D will also move half as far as A moved. Further analysis of the rack and pinion differential is identical with that of the bevel gear differential.

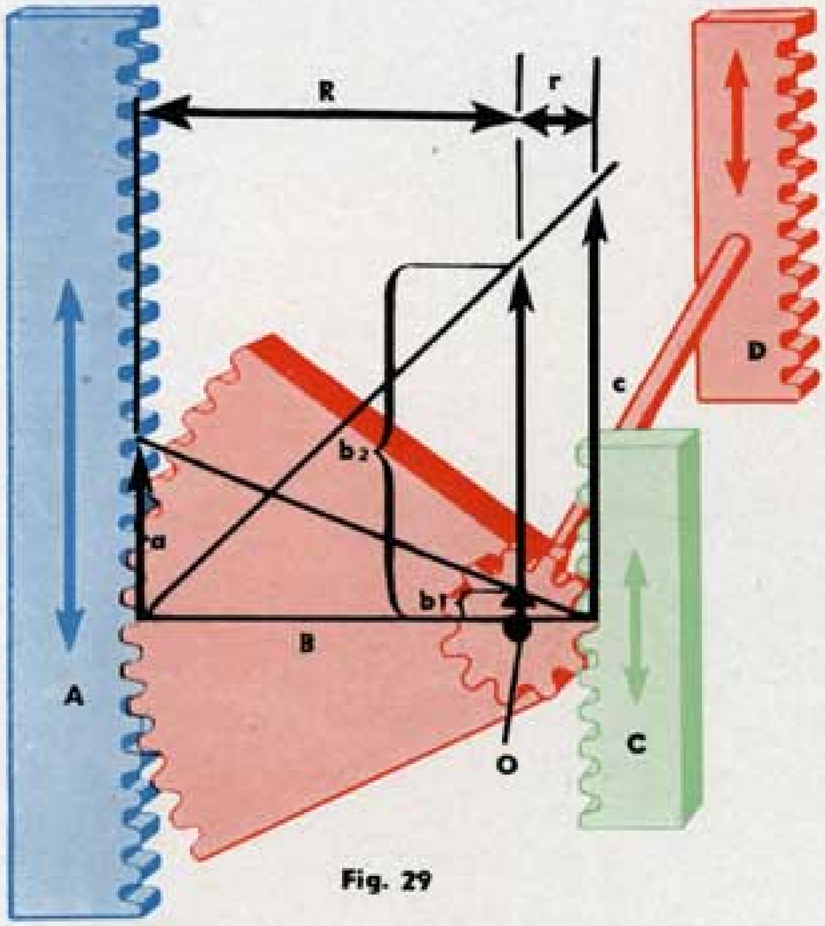


Fig. 29

Another type of differential is illustrated in Fig. 29. In this type, which is a variation of the rack and pinion differential, the two inputs are displacements of the racks A and C. The combination sector gear and pinion B transmits the linear motion to carriage D which also moves back and forth. With this type of differential the motions of the racks A and C do not have an equal effect on the motion of the follower. The movement of O due to displacement a of the rack A is b1. Likewise, the movement of O due to displacement c of the rack C is b2. The total movement of O is equal to the sum of the two components or, b1+b2.

However, since the triangles are similar

$$\frac{b1}{r}=\frac{a}{R+r}$$

or

$$b1=\frac{ar}{R+r}$$

Also,

$$\frac{b2}{R}=\frac{c}{R+r}$$

or

$$b2=\frac{cR}{R+r}$$

Therefore, the total movement of O equals

$$\frac{ar}{R+r}+\frac{cR}{R+r} \text{ or } \frac{ar+cR}{R+r}$$

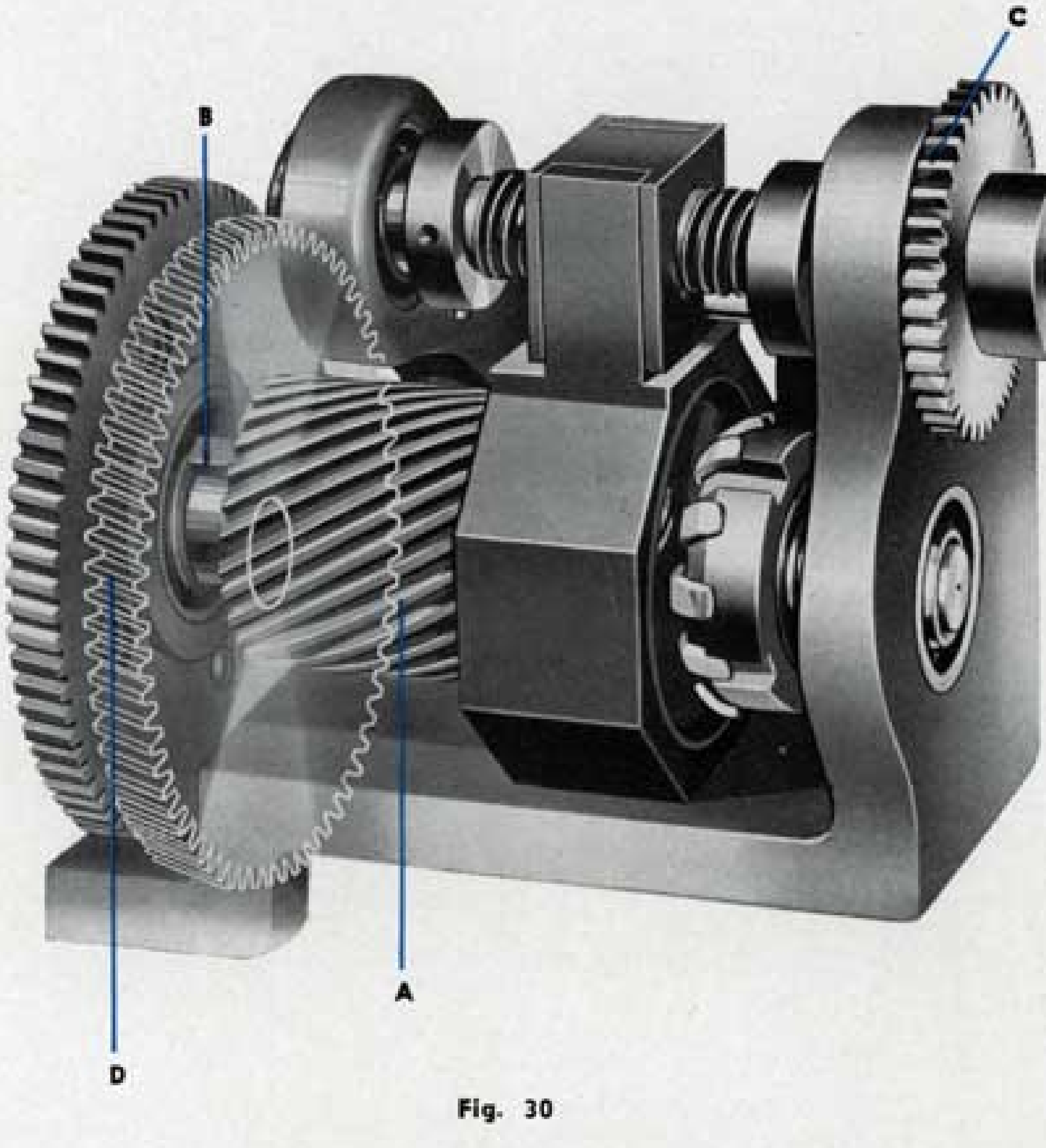


Fig. 30

An unusual application of the differential principle is shown in Fig. 30. The helical pinion A can be moved axially on shaft B. This movement is accomplished by turning the input gear C which rotates a threaded shaft on which is mounted a carriage. This carriage is fastened to the pinion A and carries the pinion with it as it moves along the threaded shaft.

The pinion A meshes with a helical gear D so that as the pinion moves axially, it is also turned an amount which depends upon the magnitude of the axial movement. In this respect it acts like a screw. In addition the pinion receives a rotary input from the helical gear D so that the output shaft B receives the added motions.

INTEGRATORS

Another of the mechanisms which is used in the Data Computer for calculating is the integrator. This device is used for multiplication, and further, it sums up the instantaneous products as the multiplier or multiplicand vary.

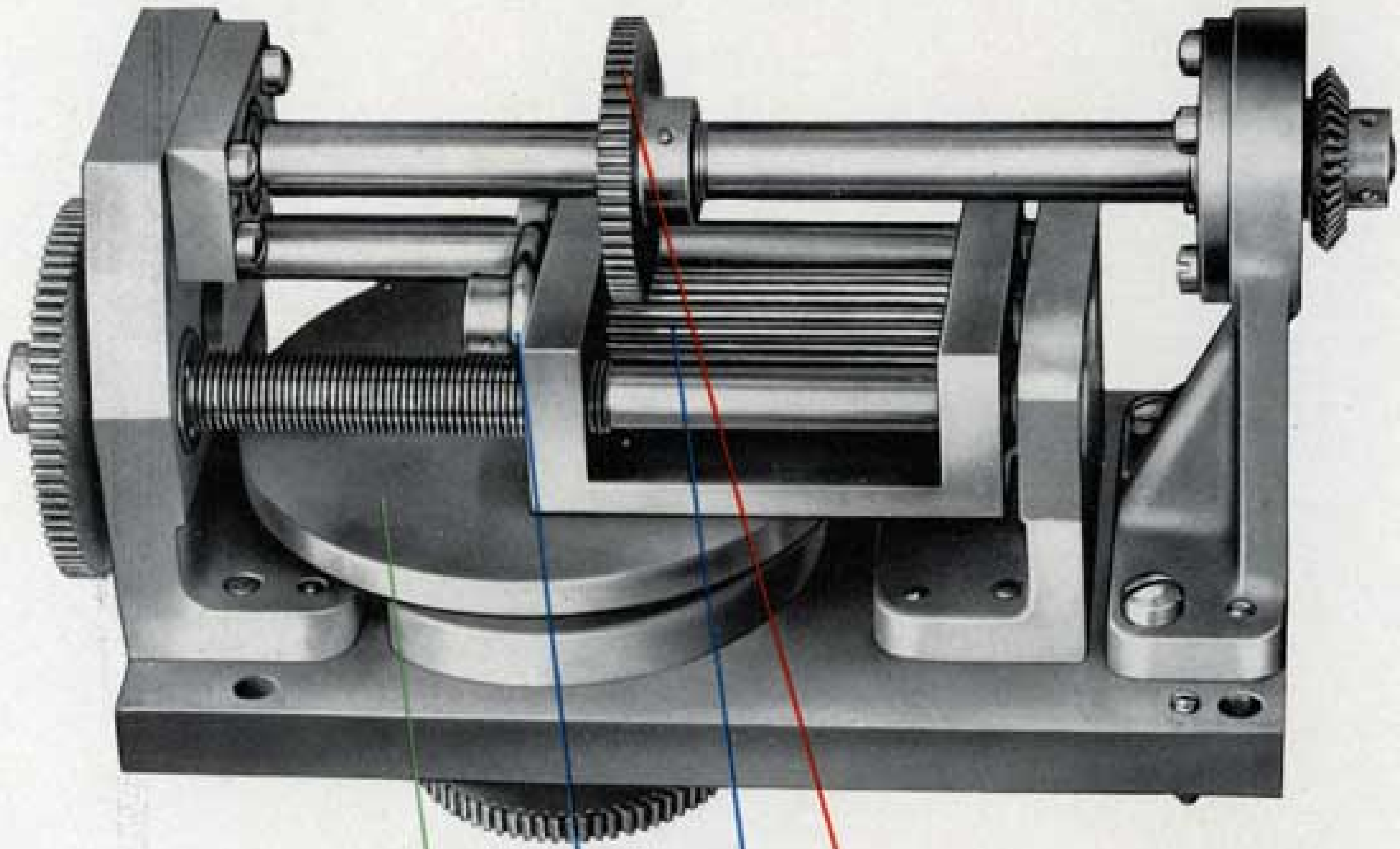


Fig. 31

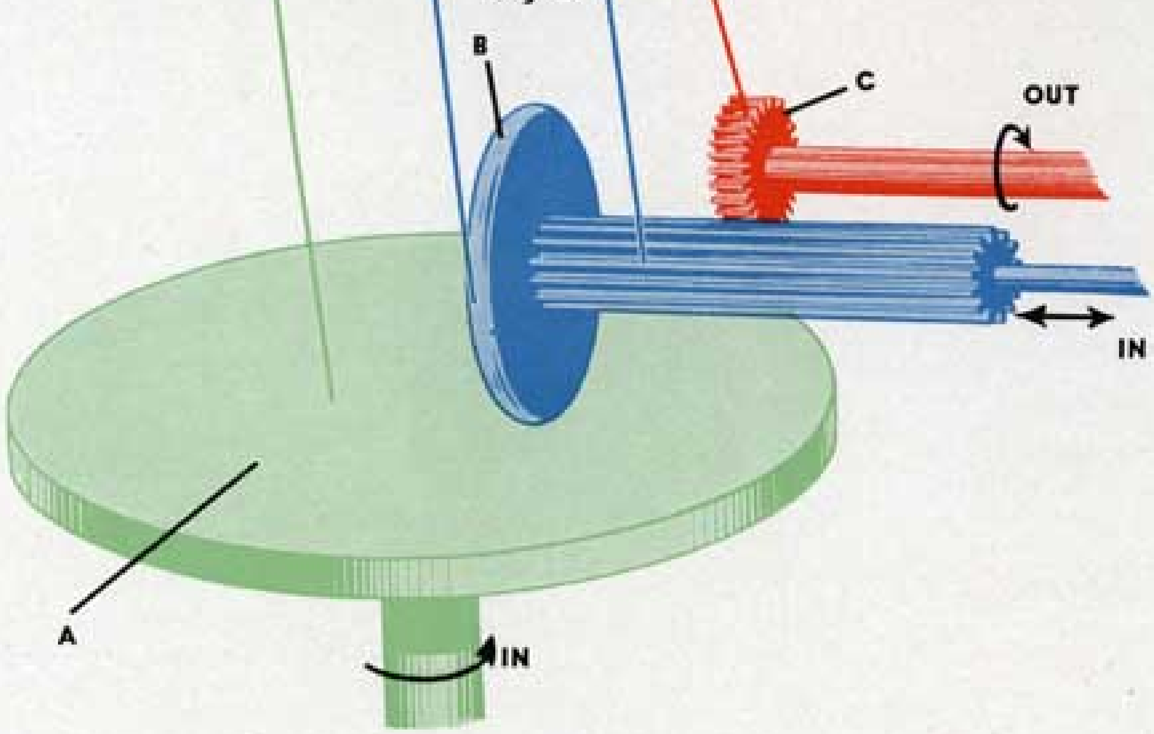


Fig. 32

When used in conjunction with a motor and a follow-up head, this unit may also be used for division and will sum up the instantaneous quotients as the divisor or dividend vary. This latter use of the integrator is explained on Page 51.

The integrator is illustrated in Figs. 31 and 32. One of the inputs consists of rotation of the large disc A, and the other input consists of locating the follower roller B at various radii on the disc. As the disc revolves it causes the roller to rotate and transmit the motion to the output pinion C. The amount of rotation of B depends upon its distance from the center of A and upon the rotation of A. For a given disc speed, zero rotation results when the point of contact is at the center of the disc and maximum rotation results when the point of contact is at the outside edge of the disc.

Fig. 33 represents motion of the disc from position 1 to position 2 through the angle M. If a point a is at the radius r, this point moves through the arc ab during the rotation.

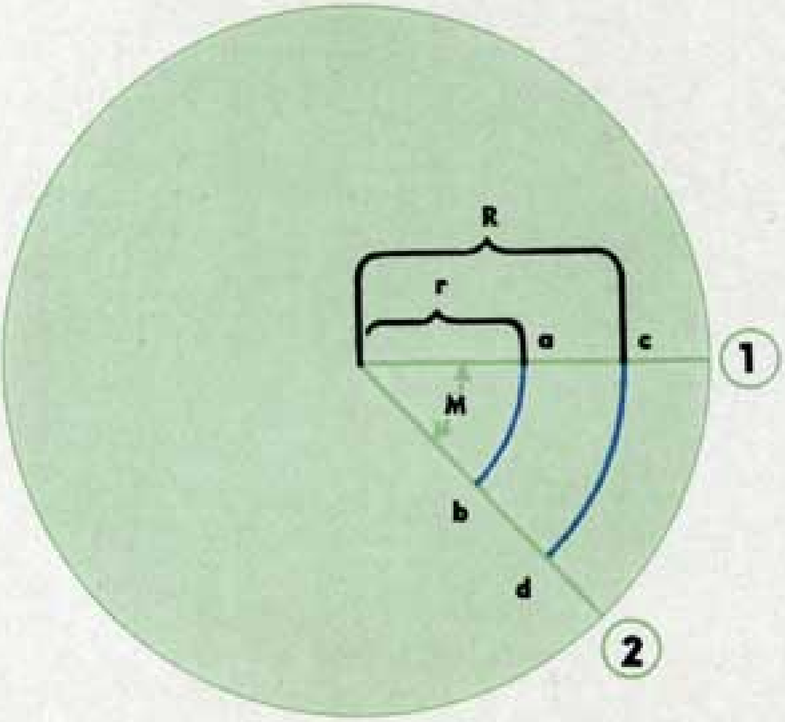


Fig. 33

$$\text{arc ab} = M \times r \qquad \text{I}$$

where the angle M is expressed in radians. When another point c is at a radius R, its movement equals the arc cd.

$$\text{arc cd} = M \times R \qquad \text{II}$$

Where the angle M is again expressed in radians. Then from equations I and II

$$\frac{\text{arc ab}}{\text{arc cd}} = \frac{Mr}{MR} = \frac{r}{R} \qquad \text{III}$$

If the follower rolls on the disc without slipping, it will roll an amount equal to the arc ab when the point of contact is a distance r from the center. Therefore, the rotation of the follower equals the amount $M \times r$. Also it can be seen from Equation III that the amount of movement is directly proportional to the radius. When the radius is zero or when M is zero, $M \times r = 0$ and the follower does not move. Since the rotation of the follower equals $M \times r$ the mechanism creates the sum of instantaneous products of M and r as either or both of these quantities vary. When neither M nor r vary the integrator operates as a simple gear ratio and the result is pure multiplication.

RESOLVER

Another of the calculating mechanisms used in the Computer is the resolver. This device is shown in Figs. 34 and 35. The resolver has two sliding carriages, A and B, which move in directions at right angles to each other. That is, carriage A moves up and down, whereas carriage B moves from side to side. The position which each carriage takes depends upon the position of the pin F and hence the blocks C and D. The pin is free to rotate in each of the blocks C and D which may travel in the slots of carriages A and B.

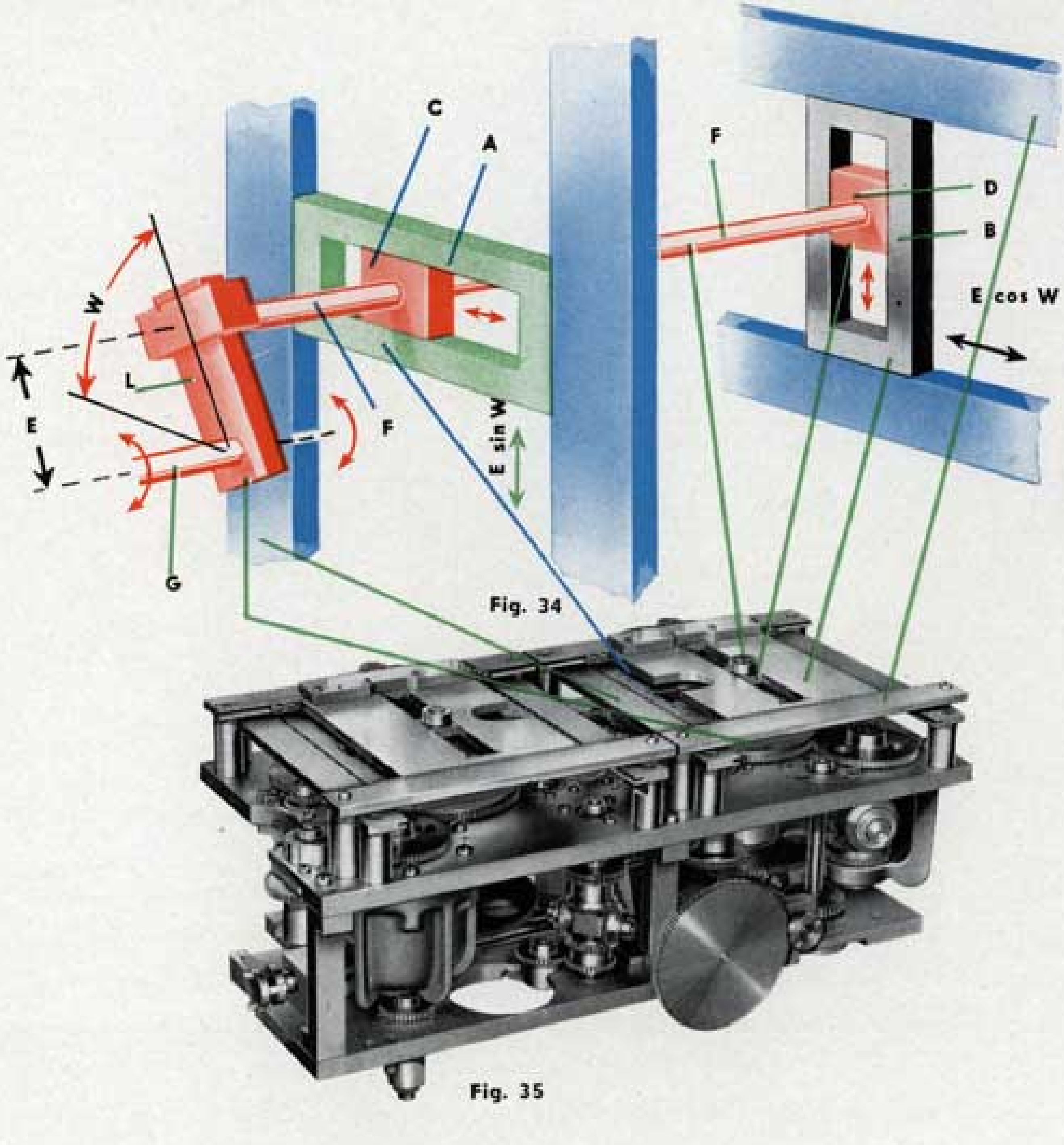


Fig. 34

Fig. 35

When the input shaft G rotates, pin F moves along an arc whose radius is E. Due to movement of pin F, the block C moves to a new location. However, in moving the block C, it is found that it can slide from side to side freely in the carriage A. Although it is not restricted in its side to side motion, the up and down motion of the block causes the carriage A to move up and down.

The block D also has the same movement as block C but it is permitted to slide up and down in the carriage B. Therefore, since the side to side motion of D is restricted, the carriage B must move from side to side with the block.

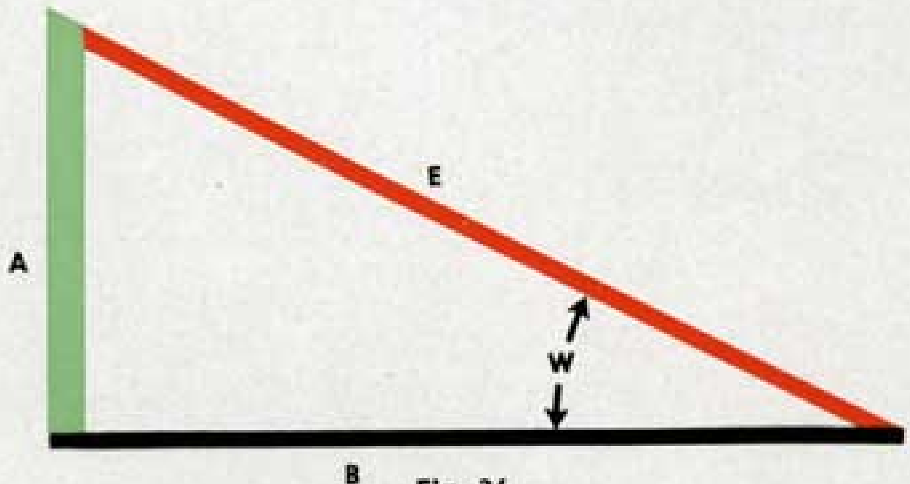


Fig. 36

From the right triangle in Fig. 36

$$\sin W = \frac{A}{E} \qquad \text{or} \quad E \sin W = A$$

$$\cos W = \frac{B}{E} \qquad \text{or} \quad E \cos W = B$$

Any position of the arm L of the resolver determines some angle W. The carriage A moving up or down gives a position which determines $E \sin W$, while the motion of carriage B moving from side to side gives $E \cos W$.

A simplified form of resolver has an arm E′ which is not adjustable. This variation changes the outputs to $\cos W$ and $\sin W$ if the design is such that E may be used as equal to unity.

Another variation of the resolver is shown in Fig. 37. In this device we have two separate arms, which are always in positions 90 degrees apart, and a carriage for each which moves from side to side. Therefore, each carriage will produce the cosine component of the angle between the arm and the horizontal. However, when the upper arm is at an angle W the lower arm is at the angle 90°—W as shown in Fig. 37.

since $$\sin W = \cos(90° - W),$$

the lower carriage not only gives E cos (90°—W), but also E sin W. The upper carriage gives E cos W. This variation of the resolver is used when it is desired to have the two carriages move in the same direction.

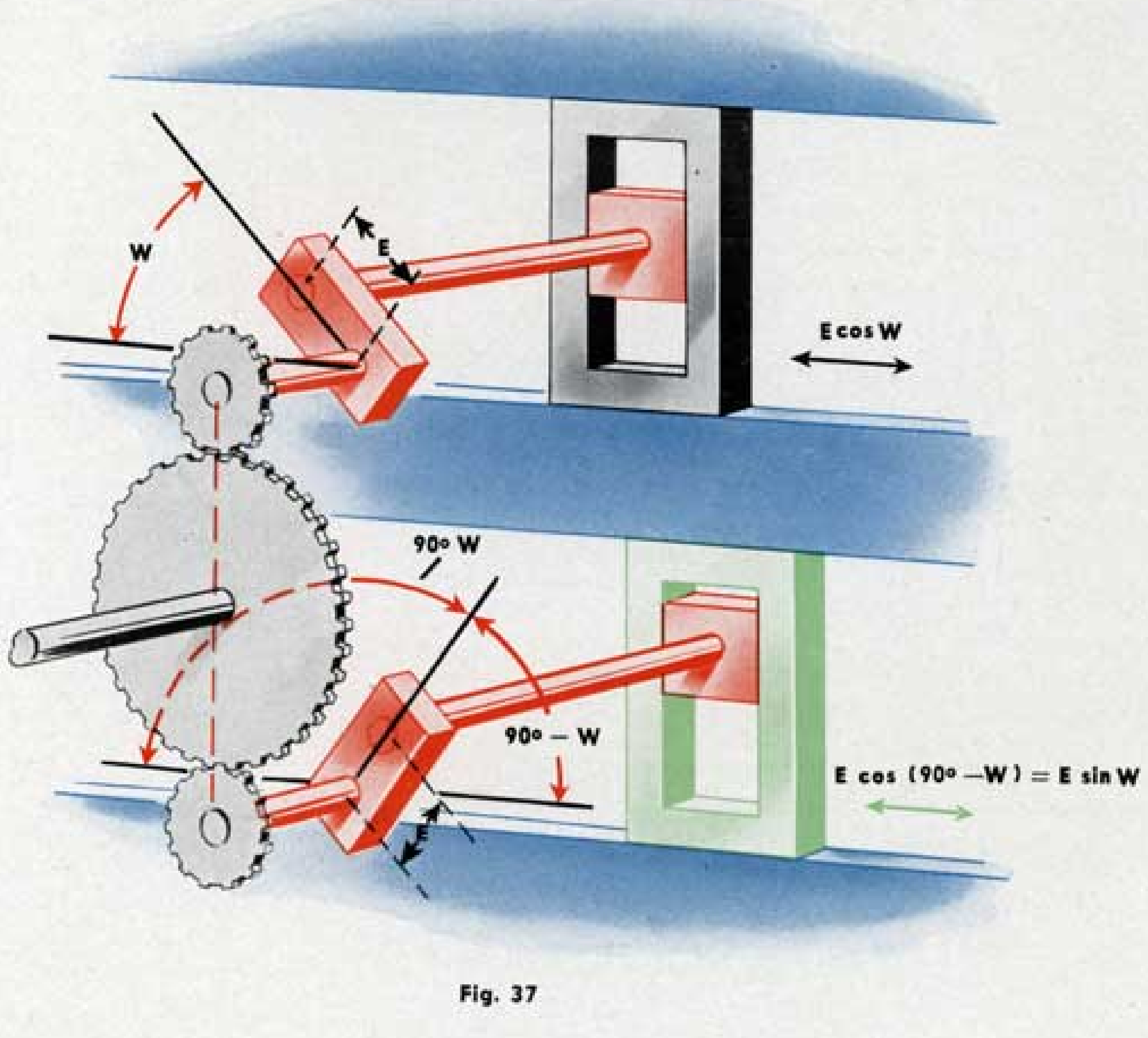
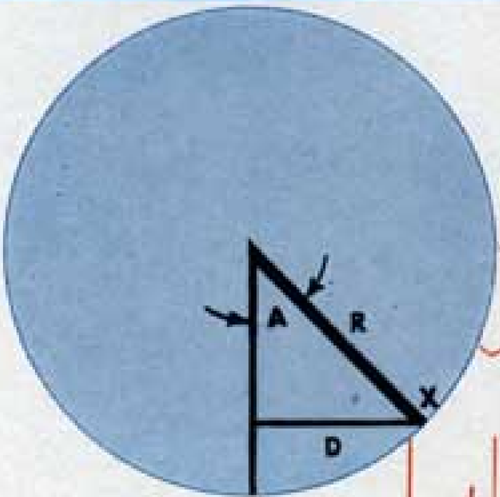


Fig. 37



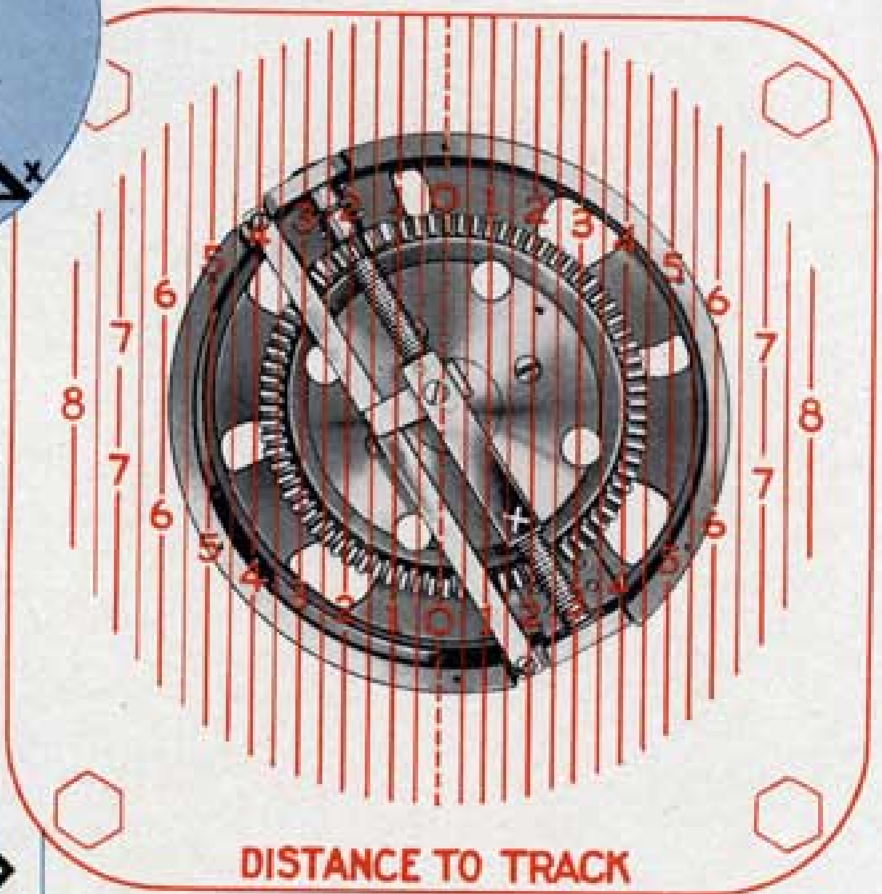


Fig. 38

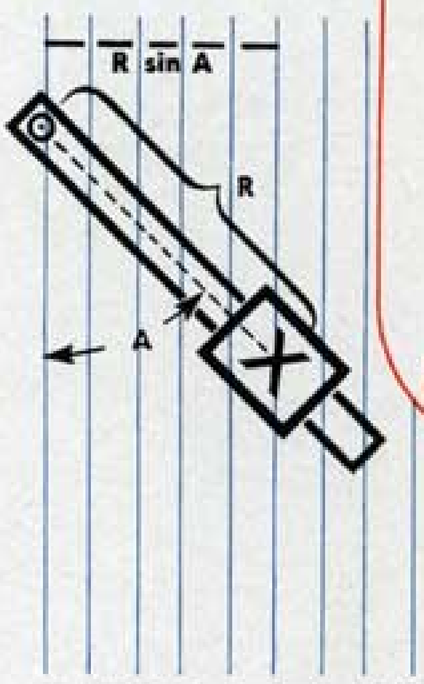


Fig. 39

In the study of trigonometry it is found that in any right triangle, as shown in Fig. 38,

$$\sin A = \frac{D}{R} \text{ or } D = R \sin A.$$

For different values of angle A, the length D will change and the point X will be various distances above the base of the triangle. Hence a resolver may be constructed to give values of R sin A.

In this resolver a nut travels on a threaded rod or arm. The angular position of the arm is determined by the angle A. The value of R is determined by the distance from the pivot to the X mark on the nut and is produced by rotation of the rod about its own axis. The nut is prevented from rotating, and as the rod rotates, the nut travels axially along it. R sin A is read from the intersection of the X mark with the vertical R sin A graduations. R sin A may be varied either by changing angle A, changing the position of the nut on the arm, or both.

PROPORTIONATOR

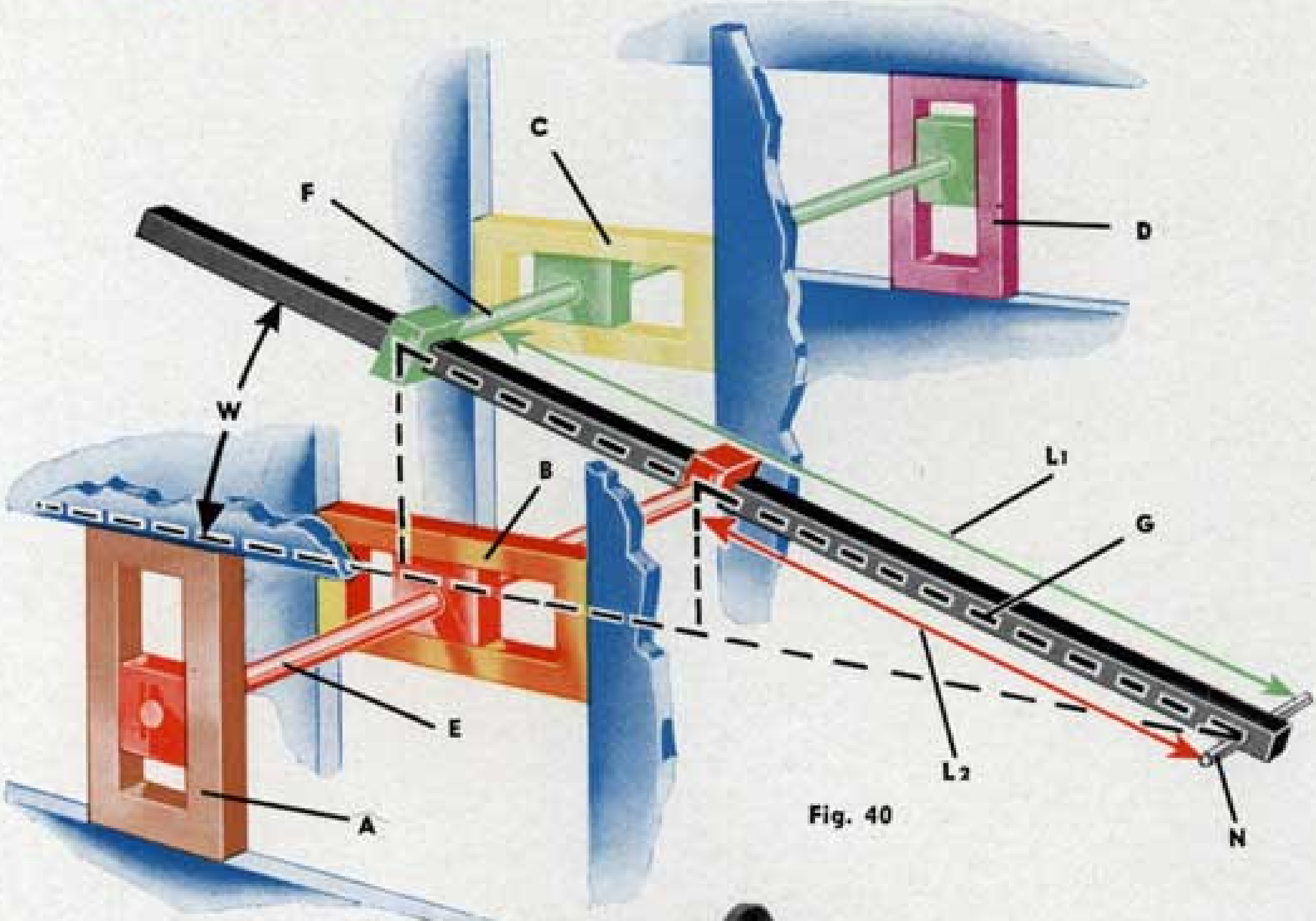


Fig. 40

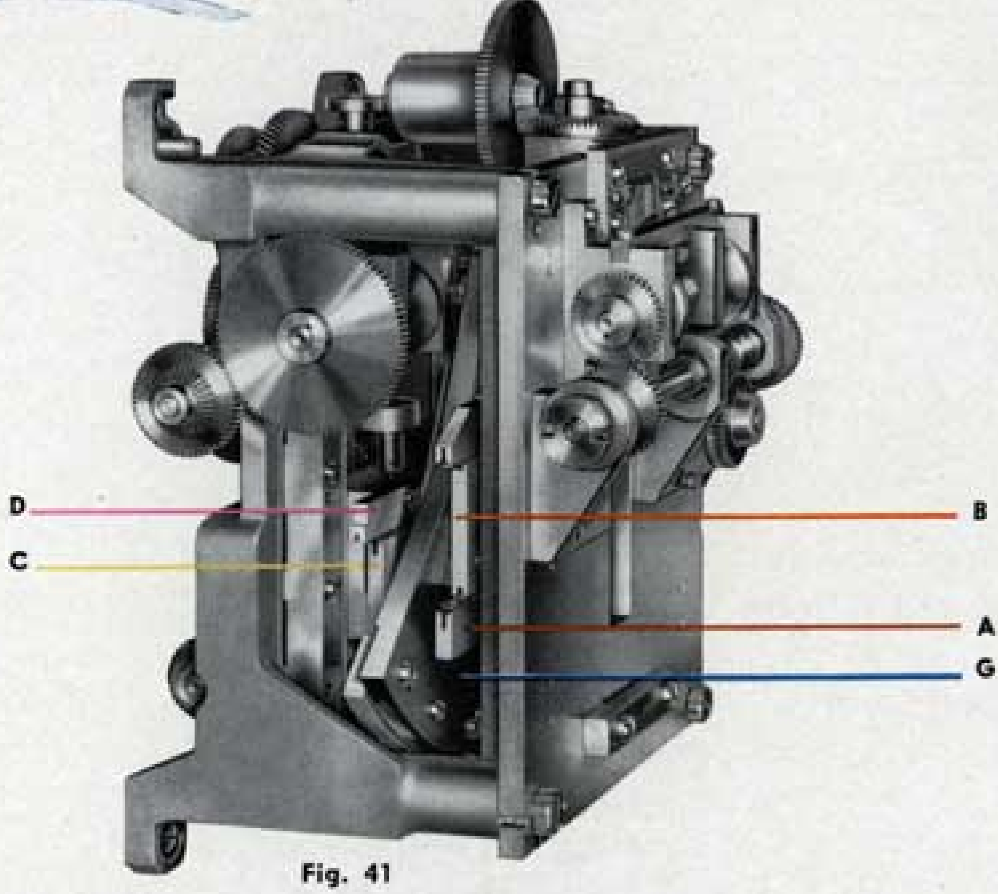


Fig. 41

Another type of mechanism is the proportionator illustrated in Figs. 40 and 41.

This device has an arm G which is pivoted at one end on the shaft N. There are two sets of sliding carriages, similar to those of the resolver, which are mounted on the pins E and F. The pins are fastened at the distances L1 and L2 from the fixed pivot to blocks which can slide along the arm G.

For any angular movement of the arm, the carriages B and C move up or down and displacements are proportional to L2 and L1. In addition, the carriages A and D also move, but from one side to the other, for displacements proportional to L2 and L1.

If we refer to Fig. 42 it can be readily seen that since the triangles are similar,

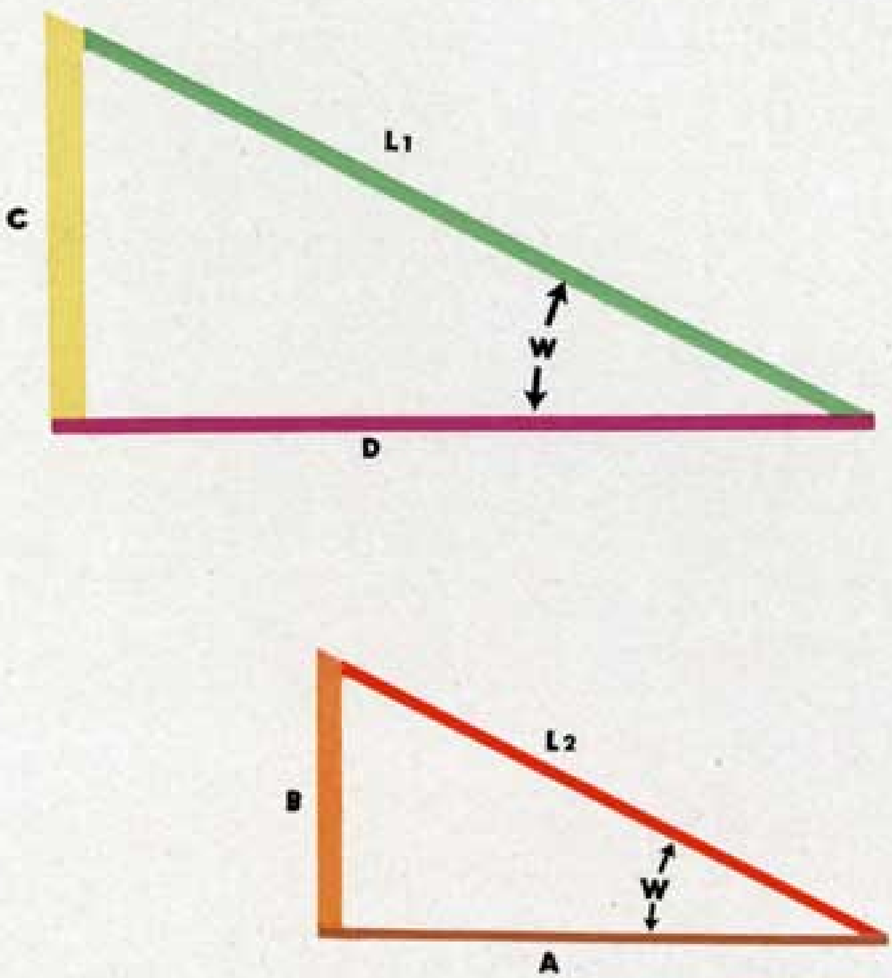


Fig. 42

$$\frac{C}{L1}=\frac{B}{L2}$$

and

$$\frac{D}{L1}=\frac{A}{L2}$$

or

$$\frac{C}{D}=\frac{B}{A}$$

Further

$$\tan W=\frac{C}{D}=\frac{B}{A}$$

or $$W=\tan^{-1}\frac{C}{D}=\tan^{-1}\frac{B}{A}$$

That is, the sides of each triangle are proportional to those of the other. The proportionator does nothing more than create a pair of similar triangles. If we have inputs such as A, D, and W, the outputs will be B and C proportional to A and D respectively, and will remain proportional as W is varied although their respective magnitudes will change.

FOLLOW-UP HEAD

The follow-up head, shown in Fig. 43, is used in several places in the Computer. There are two distinct functions which it is able to perform. First, it may be used to increase the driving power of mechanisms, and second, it may be used to match mathematical quantities in the solution of equations and continuously keep them matched.

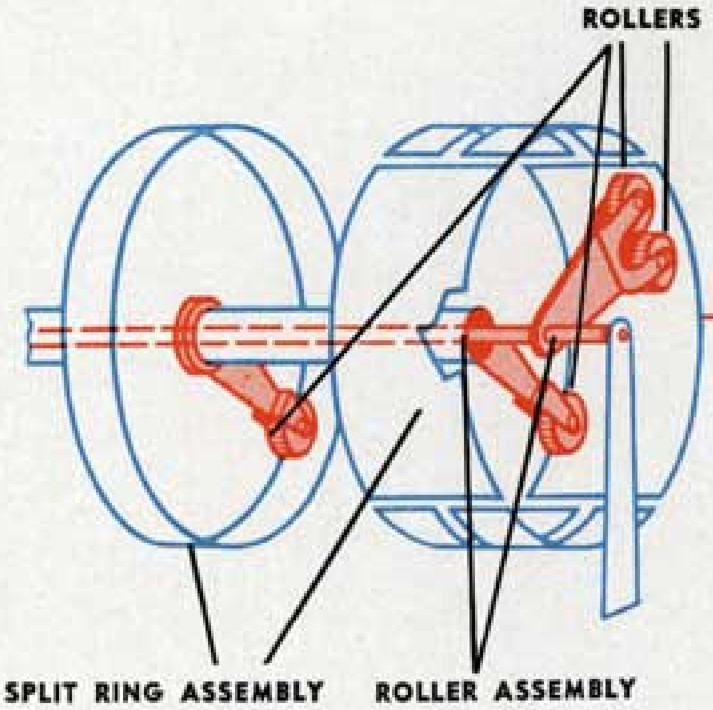


Fig. 43

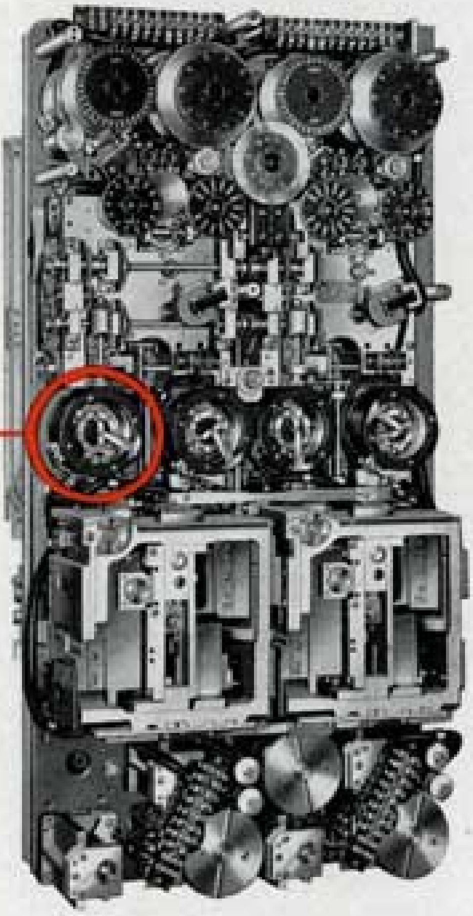


Fig. 44

This device consists of two main parts. One part is the roller assembly, the other part is the split ring assembly or body. Either part may be driven by the quantity to be matched and the other part is connected to a driving motor, either directly or through mechanism.

As the quantity to be matched moves one part of the follow-up head, the rollers make an electrical contact which excites one of the two field windings of a reversible driving motor. Immediately upon excitation, the motor turns the second part in the same direction as the first part was moved. The motor continues to run, keeping the two parts in the same relative positions as they were initially.

Follow-up heads are constructed in such a way that they will "store up" a certain number of revolutions of the driving shaft in case the electric current is shut off. When the current is turned on, the follower unit will turn until it reaches the matched position. See Fig. 59, Page 62.

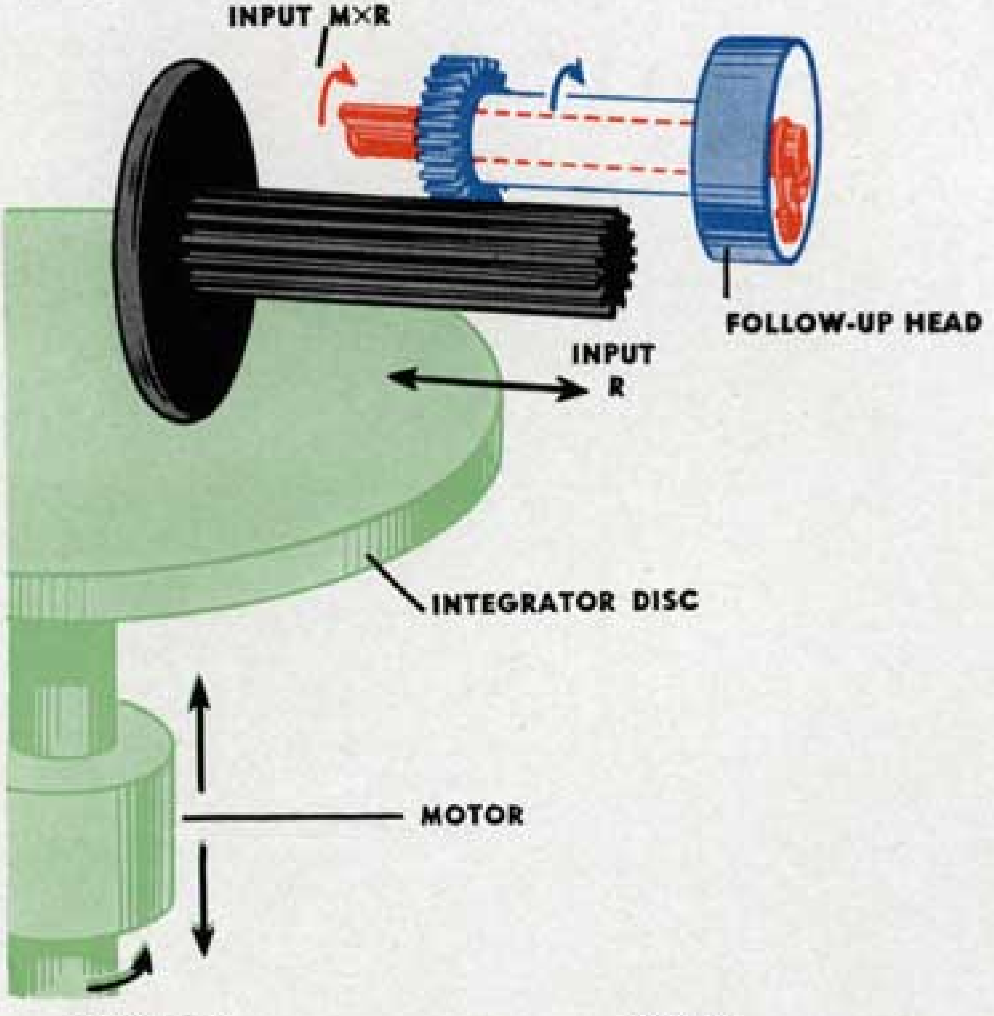


Fig. 45

By connecting other equipment to the motor shaft, it is possible to use the motor power as a driving source, which imparts the same amount of movement to a mechanical load as a weak source imparts to the follow-up head.

The follow-up head is used for matching mathematical quantities in, for example, the integrator of the divider unit when performing division. In Fig. 45, the integrator roller is positioned by one input (quantity R) and the other input (quantity M×R) operates the follow-up head rollers. The motor which drives the integrator disc is controlled by the follow-up head in such a way that the disc rotates and causes the roller to turn the correct amount M×R to make the body of the follow-up head continuously match the follow-up head rollers. This disc rotation must be the quantity M, which may then be taken from the motor shaft for other uses. The follow-up head makes it possible, therefore, to match the given quantities R and M×R to obtain the desired quantity M as an output.

CAMS

Certain complicated functions which may be expressed mathematically are difficult to reproduce mechanically without resort to the use of cams. The simplest form of cam is a wheel with some sort of irregularity on the periphery so that a follower which rides on the wheel will reproduce the irregularity in a reciprocating motion. A cam of this type is shown in Fig. 46. It is possible to design the cam so that the follower will move in such a way that it satisfies a mathematical equation. For example, it is possible to obtain a follower movement equal to K sin W as represented in Fig. 47, if K is a constant. Such a cam is constructed with gradually changing radius so that the periphery of the cam causes the follower to move up and down with the correct motion in relation to the turning of the cam. This cam is shown in Fig. 48, and is nothing more than the curve of Fig. 47, wrapped around a circle.

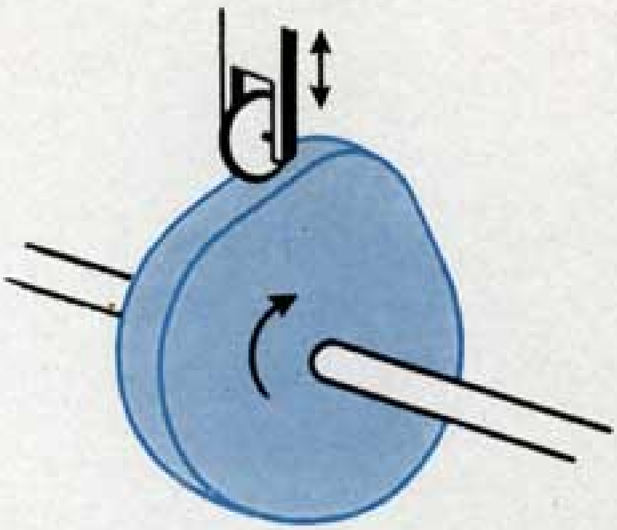


Fig. 46

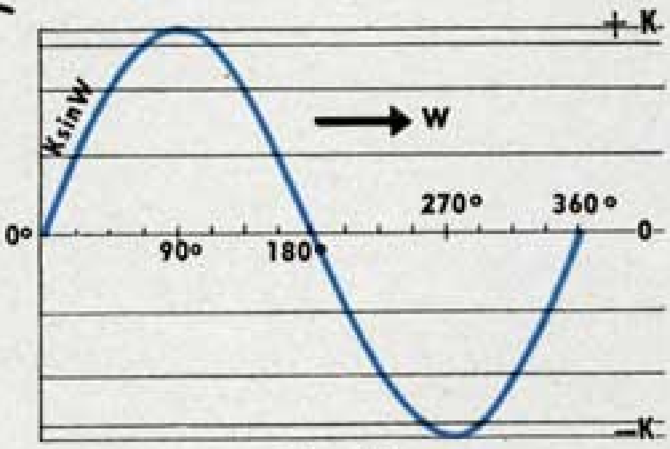


Fig. 47

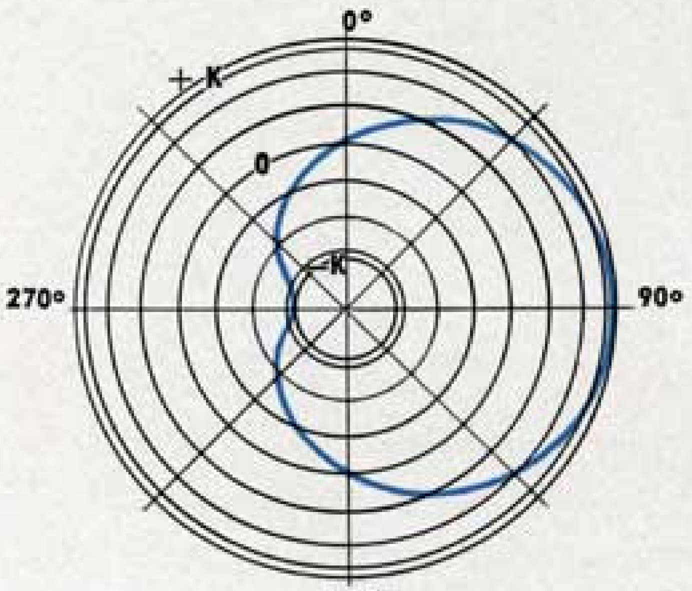


Fig. 48

If the follower is to travel along different paths with changes in setting, several cams may be provided so that selection of the proper cam produces the desired follower

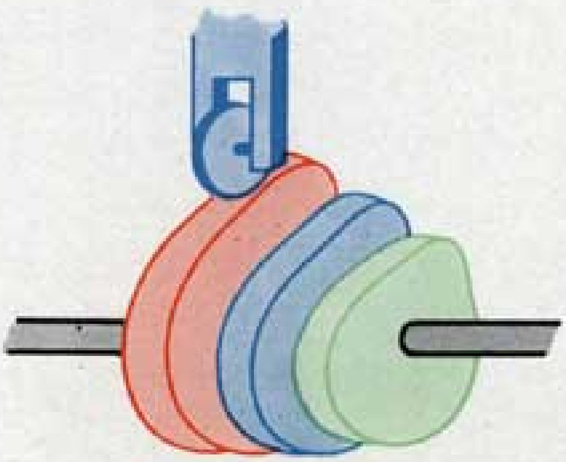


Fig. 49

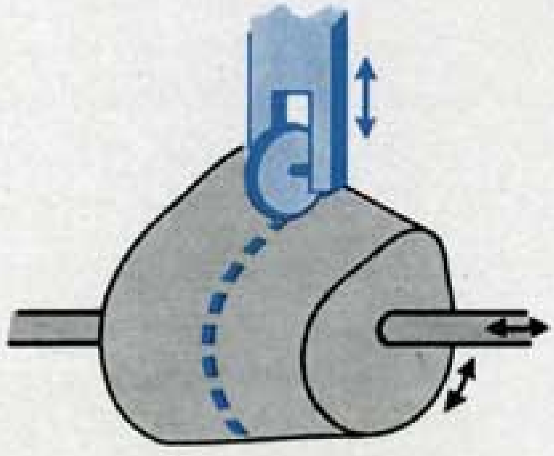


Fig. 50

motion. A set of cams shown in Fig. 49, permits the use of another variable quantity. The three dimensional cam shown in Fig. 50, is an improvement on the set. Instead of changing cams, the contour in contact with the roller is determined by the longitudinal position of the cam. This third variable is introduced by the axial positioning of the shaft.

In the Torpedo Data Computer the three dimensional cam is used in a special form. The cam is split so that the two halves may be moved relative to each other. This type

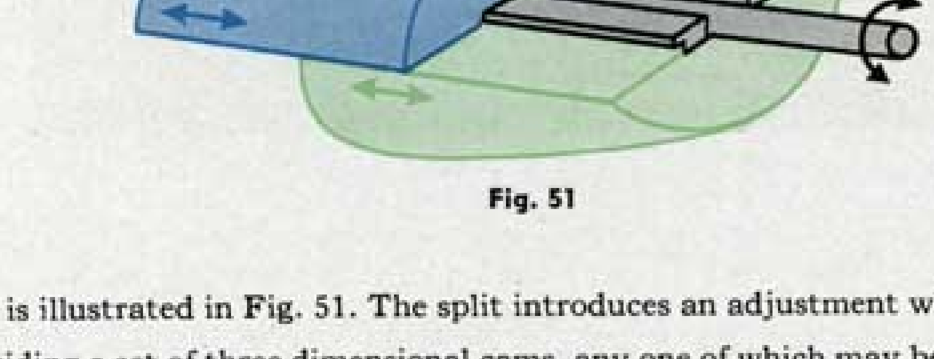


Fig. 51

of cam is illustrated in Fig. 51. The split introduces an adjustment which is equivalent to providing a set of three dimensional cams, any one of which may be selected depending upon the position of the two cam halves.

DIALS

Dials may be constructed in such a way that by setting values of indicated quantities adjacent to each other, the sum of two other quantities will be set into the instrument. For example the Target Length Dial is used for adding quantities P2 and 3SR/2889. The inner scale graduations indicate values of 2P2 or Target Length whereas the outer scale indicates values of SR/1000. For any value of Target Length set opposite a value of SR/1000, the dial position determines P2+3SR/2889 for the particular values of 2P2, S and R. If S or R change 2P2 is set opposite a new value of SR/1000 and the proper change in P2+3SR/2889 will have been made. The dials are graduated in such

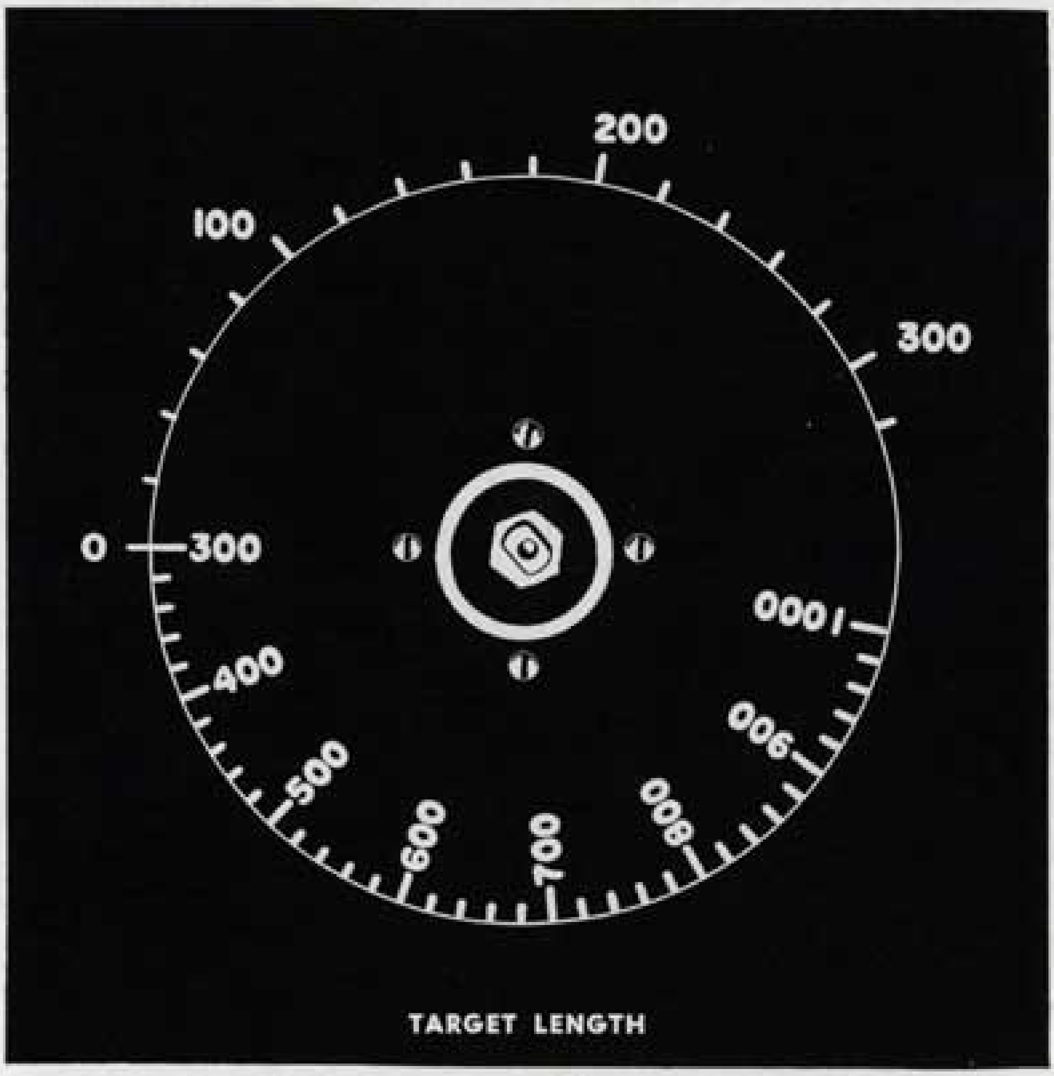


Fig. 52

a way that two easily obtainable quantities are used to produce the addition of more complicated quantities which would take too much time to determine. It is for this reason that the dial graduations appear inconsistent, that is, when 300 is set opposite 100, 400 is not opposite 0. This dial is shown in Fig. 52

FUNCTION

The Torpedo Data Computer is divided into two sections, the first of which contains the Position Keeper and the Sound Bearing Converter. The second section consists of the fwd and aft Angle Solvers. Each of these units is made up of smaller components which may be discussed independently.

SECTION 3

GENERAL FUNCTION OF THE COMPUTER

The Position Keeper receives settings to agree with the initial observations of Relative Target Bearing and Range as well as estimates of Angle on the Bow and Target Speed. All of these quantities are set into the instrument with hand cranks. These inputs are supplemented by continuous electrical inputs of Own Course and Own Speed. Using these quantities the Position Keeper performs the following functions:

a. Assists in correcting the initial estimates.

b. Generates the values of Relative Target Bearing, Range and Target Angle with respect to Time.

c. Furnishes values of Relative Target Bearing, Range, Target Angle, and Target Speed mechanically for the fwd and aft Angle Solvers.

d. Furnishes mechanical inputs of Range, Target Angle, and Relative Target Bearing to the Sound Bearing Converter.

e. Pictorially shows the relative courses of Own Ship and Target and the Track Angle and Gyro Angles for both fwd and aft torpedoes.

f. Continuously indicates the distance to Target Track.

g. Indicates when the Position Keeper is producing a correct solution for the particular inputs which have been set in.

The Sound Bearing Converter receives, in addition to the mechanical inputs which come from the Position Keeper, a cranked-in value of P2+3SR/2889. The inputs combine in the instrument to form continuously a value of Sound Bearing which appears on the dials of the Position Keeper. A value of Sound Base Line is set into the unit to take care of parallax due to the distance between the sound bearing device and the periscope position for a given ship.

The fwd Angle Solver receives, in addition to the mechanical inputs from the Position Keeper, settings of fwd Offset Angle, Corrected Torpedo Speed as Depth Set, Torpedo Run Difference and Reach as Keel Depth, and Torpedo Turning Radius. It also receives adjustments for Tube Base Line and the difference between right and left values of Reach and Turning Radius. With these inputs it performs the following functions:

a. Solves the torpedo problem with respect to the torpedoes in the fwd tubes, allowing for base line between the periscope position and the fwd torpedo tubes.

b. Generates values of fwd Gyro Angle Order and fwd Torpedo Run and transmits the value of fwd Gyro Angle Order to the fwd Gyro Setting Indicator Regulator.

c. Indicates when the mechanism is giving the correct solution based upon the values which it has received.

d. Represents on the Own Ship and Target Dials of the Position Keeper, the fwd Gyro Angles and fwd Track Angles.

FUNCTION

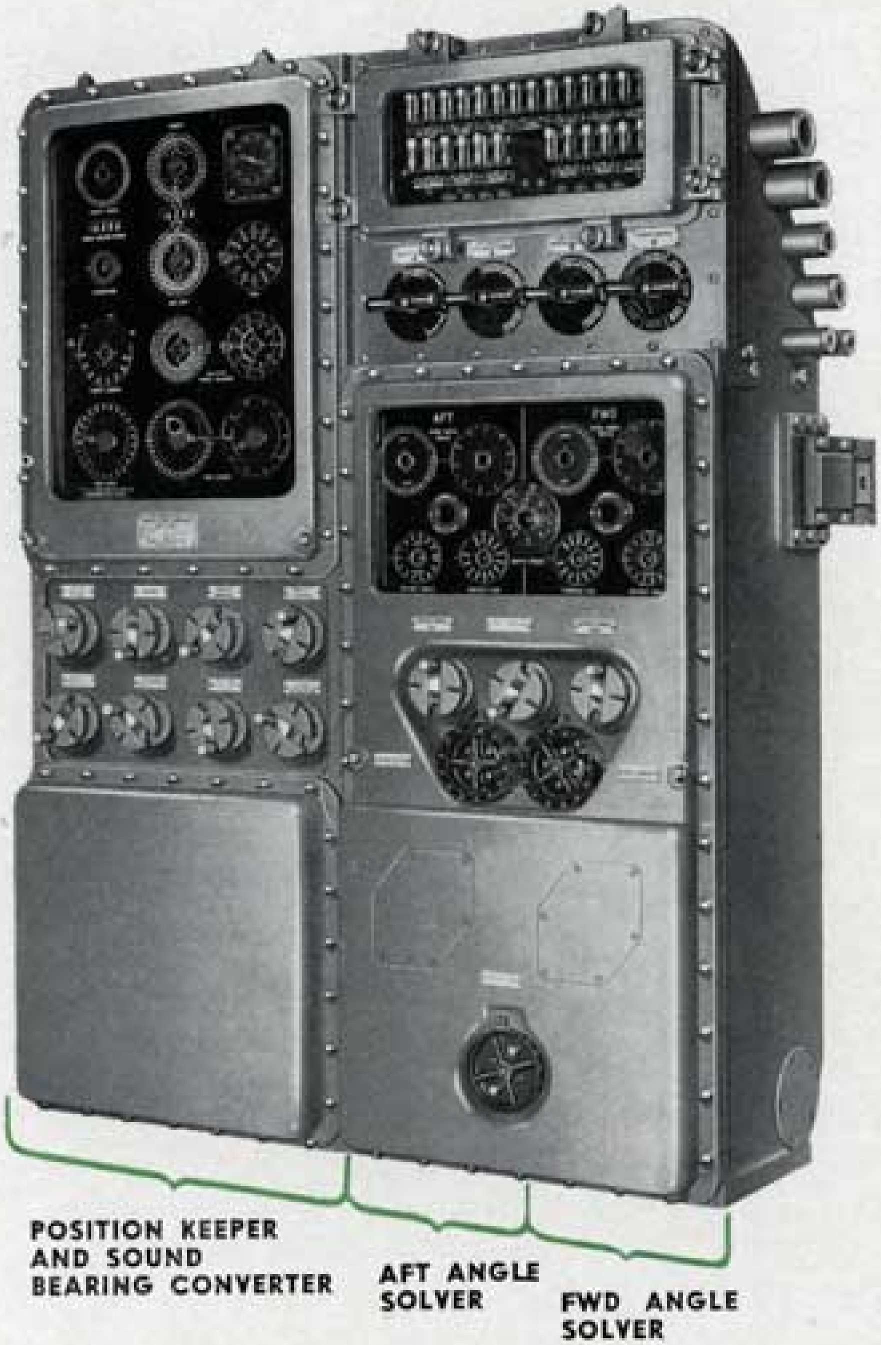


Fig. 53

The aft Angle Solver performs similar functions with respect to the torpedoes in the aft torpedo tubes that the fwd Angle Solver performs for the torpedoes in the fwd torpedo tubes.

The small units which make up the four components of the Torpedo Data Computer are connected with suitable gearing and supplemented with dials to form the large sections. Since these units may be taken out of the instrument individually, their functional diagrams will be shown separately. The assembled functional diagrams will show the interconnection between the units as well as the units themselves, to make up the complete picture.

MECHANICAL FOLLOW-UP HEADS

Follow-up heads are used in both the Position Keeper and the Angle Solver, and the following general description applies to follow-up heads found in either unit.

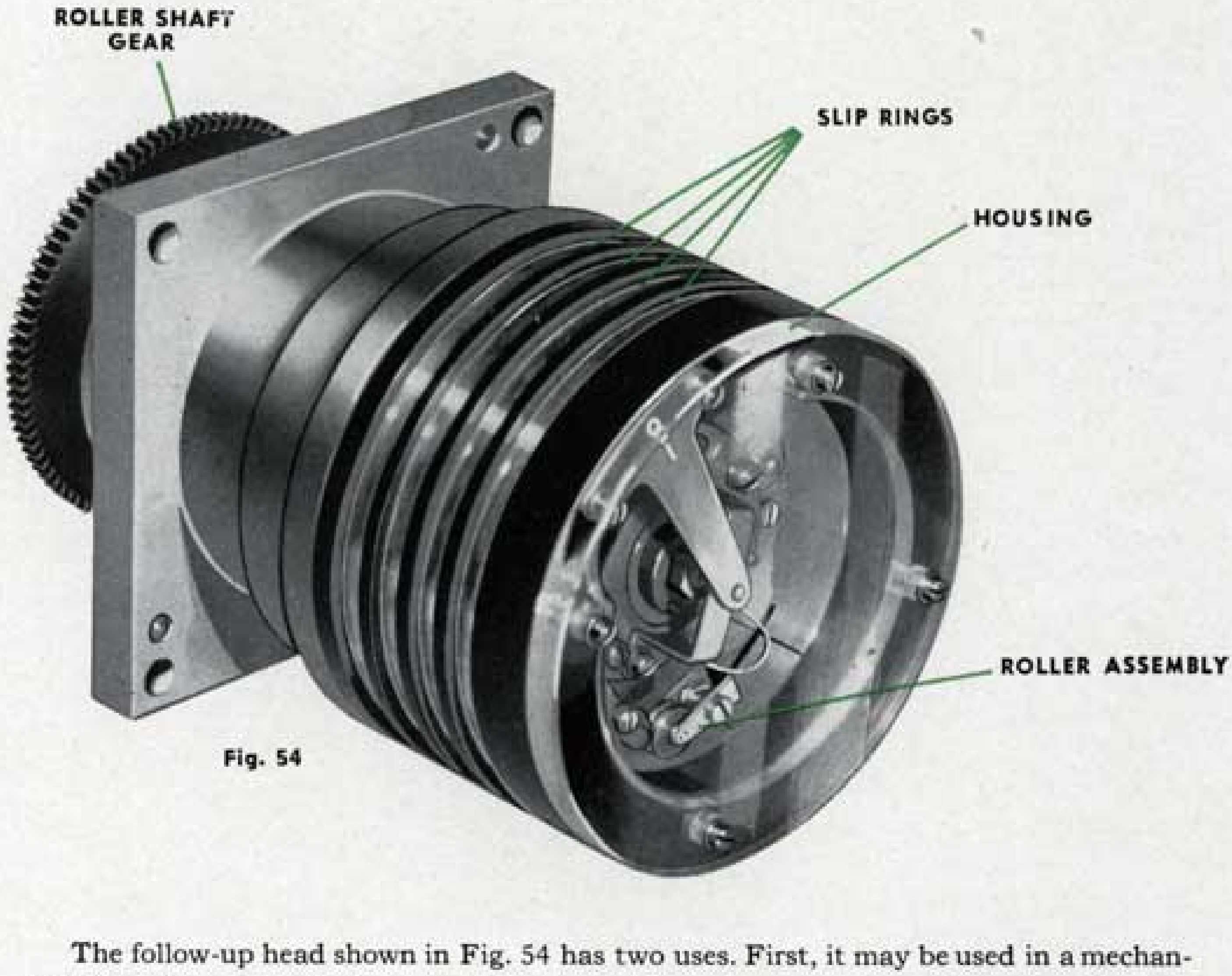


Fig. 54

The follow-up head shown in Fig. 54 has two uses. First, it may be used in a mechanical circuit to electrically control the direction and amount of rotation of a follow-up motor, which increases the driving power in the system. The follow-up head may also be used for matching mathematical quantities, as mentioned in the section on Fundamentals, Page 50.

In most applications in the Torpedo Data Computer, the input drive displaces the head of the unit, while the response drive from the follow-up motor enters directly (or indirectly through an element in the mechanical circuit) and matches the input drive by displacing the rollers. However, it can be and is used with the response drive connected to the head and the input connected to the rollers.

The mechanism is shown diagrammatically in Fig. 55. The main driving shaft A is directly connected to the high speed rollers and also to a reduction gear train B, which, through a transfer gear assembly, drives a low speed roller.

The gears B provide a 9 to 1 reduction in speed which is delivered to the locking cam C and the intermittent gear D. The upper half of cam C is a portion of a gear made with a pitch diameter for 20 teeth, only two of which are left on the periphery, as shown. Therefore, the two teeth require 2/20 or 0.1 revolution for their action period, being inactive then for the remaining 0.9 of each revolution.

Since C only moves 1/9 the speed of A, the shaft A must turn 9×0.1 or 0.9 revolution in order to make the two teeth on cam C go through a complete transfer. When the transfer mechanism is in the position shown in Fig. 56, the intermittent gear is halfway through a transfer motion, and it will require only 0.45 revolution of A in either direction to complete the movement. After a transfer has been completed, shaft A must turn through 9×0.9 or 8.1 revolutions before a transfer begins again. The low speed roller is geared so that it moves 45° during a complete transfer. It is prevented from moving during 8.1 revolutions of shaft A by the locking cam C. During the transfer motion a notch in the cam permits passage of one long tooth on the intermittent gear, but further motion of the intermittent gear, which drives the low speed roller, is prevented by the lack of notches and the absence of driving gear teeth on the top half of cam C.

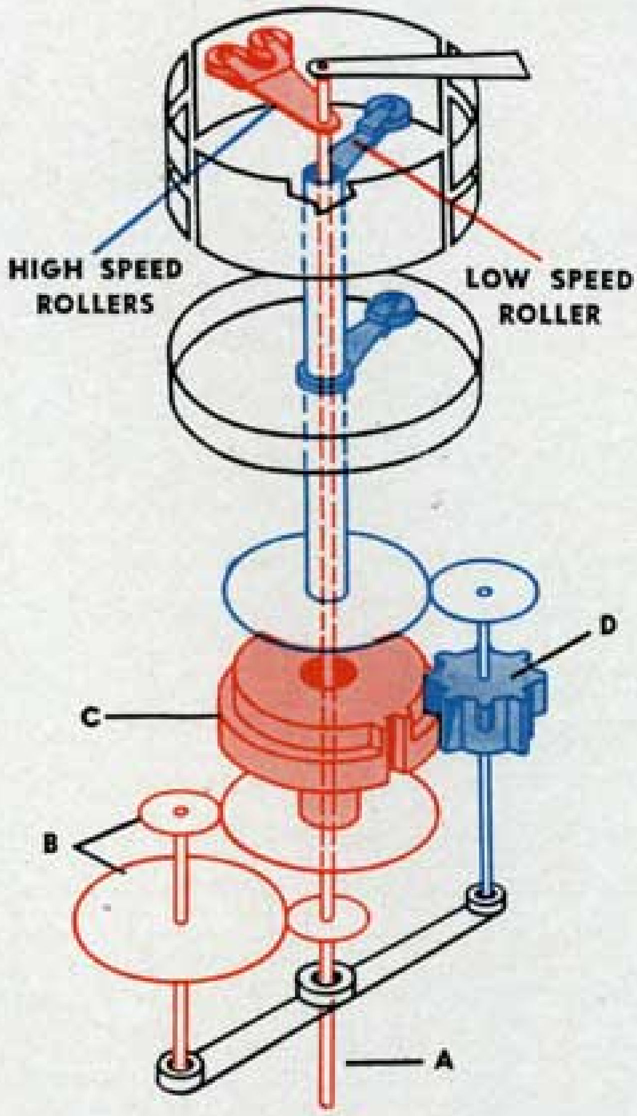


Fig. 55

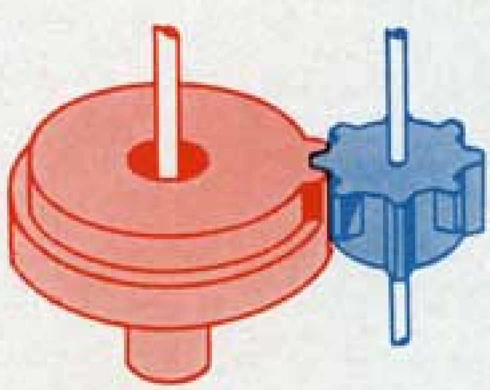


Fig. 56

Referring to Fig. 57, the constructional details of the cam C and gear D are more apparent, as is the locking action between transfers. It can be seen that the single notch in the lower portion of cam C is a continuation of the "valley" between the two driving teeth on the upper portion of the cam. The diameter of the lower part of the cam is the same as the major diameter of the gear which forms the upper portion of the cam. The diameter of the greater part of the upper portion is the same as the minor (root) diameter of the two gear teeth cut on it. When the cam and gear are in the transfer position, as shown in the figure, the two teeth on the upper part of the cam C engage and move one of the long teeth on the gear D, while the notch in the lower part of the cam allows this tooth free movement to complete a transfer, producing one quarter turn of the intermittent gear. As the tooth leaves the notch, another long tooth approaches and makes contact with the lower peripheral surface of the cam to be in position to enter the notch during its next time around. During this waiting period, therefore, two long teeth on the intermittent gear are in contact with the notchless surface of the cam, thus locking the gear in this position until the notch in the cam again arrives at one of these two teeth. During this time also, one of the short teeth of the gear D rests in the clearance space provided by the missing teeth on the upper portion of the cam, and awaits contact by one of the two teeth on the cam. The four short teeth, alternately spaced between the long teeth of the gear D, are merely for the purpose of starting motion of the intermittent gear when the cam notch has approached the position required for passage of one of the long teeth.

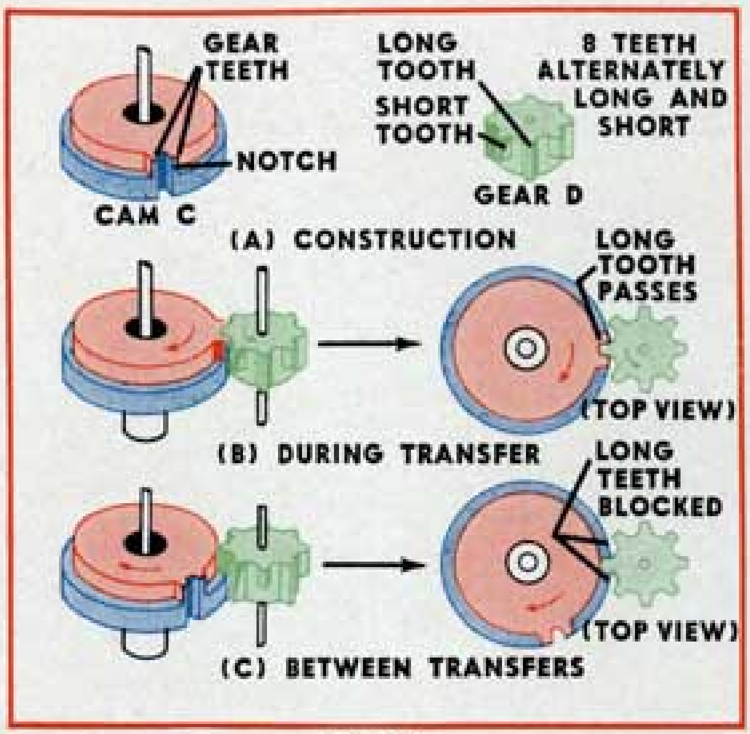


Fig. 57

This type of follow-up head has a "storage" capacity of 35.55 revolutions of shaft A, Fig. 55, Page 59, obtained as follows: Since the low speed roller only moves the amount provided by half a transfer before coming to a stop due to locking of the cam, it will move 22½ degrees (starting with the tooth in the notch). During the 22½ degree motion, shaft A (and the high speed roller) moves 0.45 revolution. The successive positions of the low speed roller may be seen in Fig. 58.

In the "matched position" of the head, which occurs when the response drive has equalled the input drive and the follow-up motor actuated by the head is no longer energized, the low speed roller is at a, the high speed rollers are on the small segment of their split ring, and the intermittent gear is in the position shown in Fig. 56, Page 59. If now the response drive remains de-energized while an input is applied to the follow-up head rollers, the following motions of the low speed roller occur.

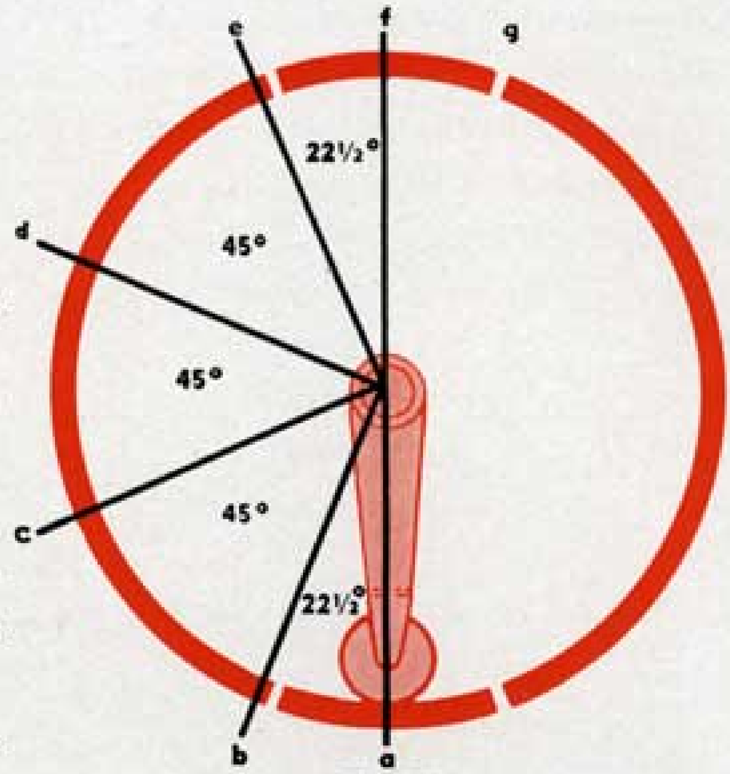


Fig. 58

After the first one-half transfer the point b is reached where the roller remains for the following 8.1 revolutions of A. Then, during the next 0.9 revolution of A the roller travels to the point c where it remains for another 8.1 revolutions of A. Traveling to point d requires another 0.9 revolution of A, and after remaining there for 8.1 revolutions of A, another 0.9 revolution carries the roller to e. Shaft A can rotate another 8.1 revolutions before it starts to move the roller again, but any further movement of the roller will bring it to a dead segment at point f. The second half of the transfer would carry the roller to the contact at g which would connect the opposite field winding of the follow-up motor and cause the motor to turn in the wrong direction for synchronizing if the response drive were re-energized. (These connections in the electrical circuit may be checked by referring to Figs. 59A, 59B and 59C on Page 62). Therefore, the total of all motion of A up to the beginning of the transfer of the roller from e to f adds up to 35.55 revolutions. This is the amount of displacement of shaft A of which the follow-up head is able to keep account. In other words, if there is any displacement of the shaft A up to a maximum of 35.55 turns the follow-up will synchronize in the proper direction to match the input quantity.

This storage capacity is obtained in the same amount (35.55 turns) in either direction from the matched position. The addition of another locking cam and intermittent gear could be made to multiply the storage capacity of the head by approximately ten to give a capacity of 359.55 turns in either direction.

Movement of the high speed rollers normally controls the follow-up motor without causing the low speed roller to leave its matched position segment. Follow-up is continuous as long as the circuit is energized. However, if the circuit is open for any reason, the follow-up motor will not run, and under such conditions the ability of the follow-up head to store up a number of revolutions is of value. When the circuit is again closed, the motor can start up in the proper direction and catch up to the driving shaft.

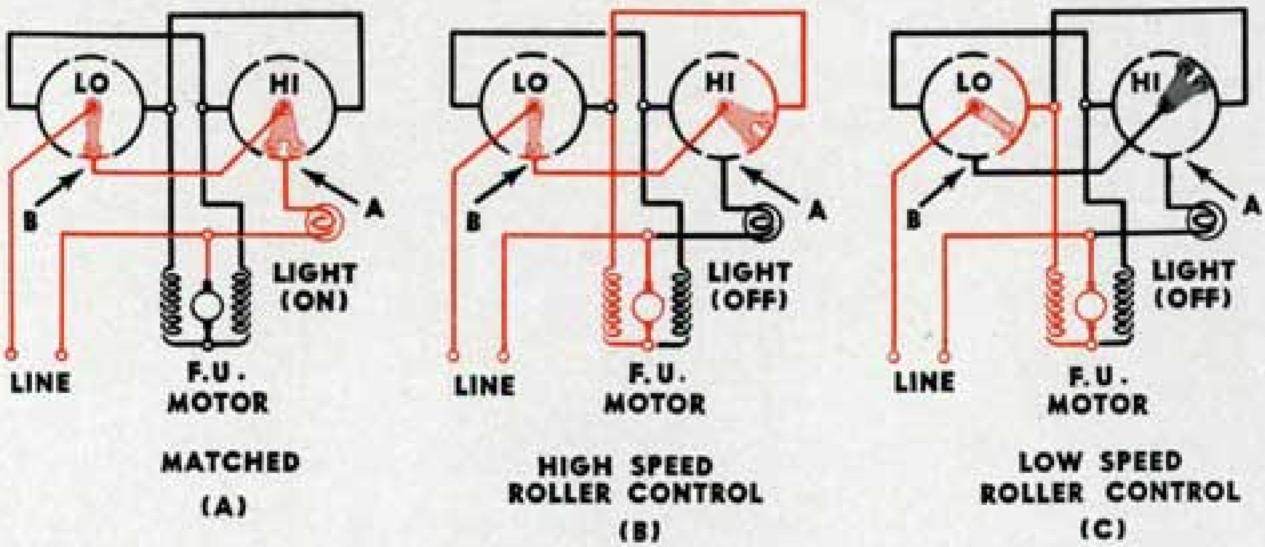
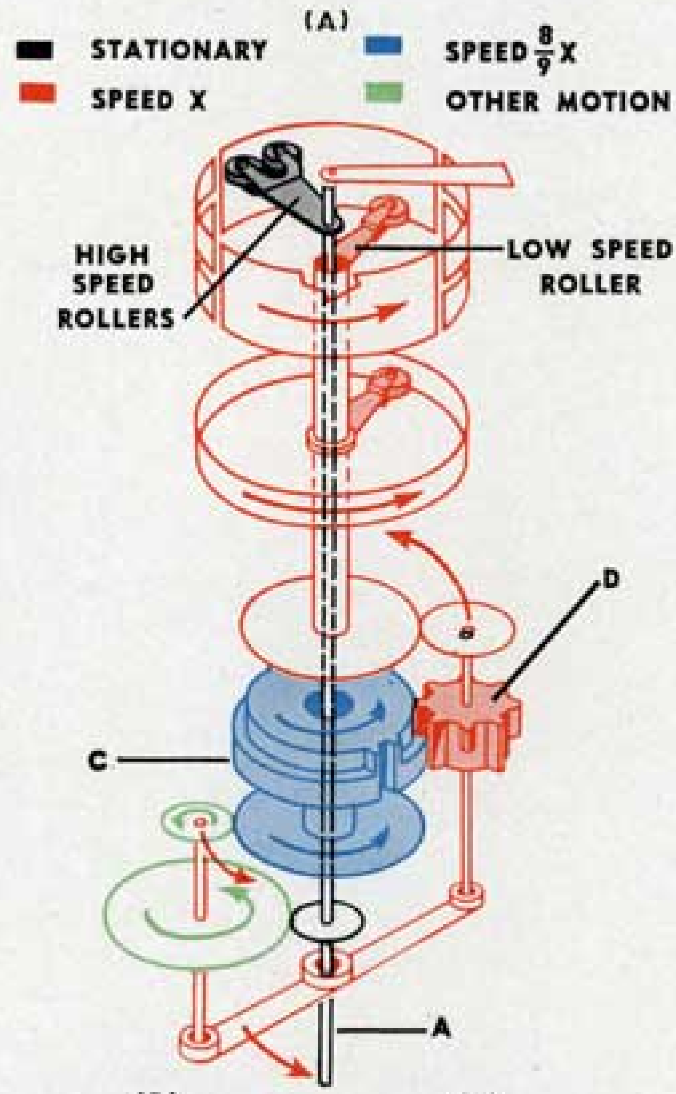


Fig. 59

Fig. 59 shows three conditions which may exist in the follow-up action. In the circuit diagrams, the red colored leads indicate energized circuits. In sketch A the follow-up head is matched; the circuit to the follow-up motor is incomplete to both fields and the indicating lamp is lighted. In sketch B the high speed rollers have been displaced a few degrees—not enough to cause transfer of the low speed roller to controlling position. Now the motor is energized by completing the circuit through the proper field to cause it to run in such a direction as to restore the original relationship between the roller and segment A. Until this matching occurs the motor runs and the indicator light is off. In sketch C the head has stored up a few turns and the low speed roller is in control of the motor. The high speed roller is no longer energized and the indicating lamp is off. As the motor runs to restore the original matched relationship, the high speed roller (or the head around the rollers) moves until a transfer places the low speed roller on segment B, thus allowing the high speed roller to assume control and bring the follow-up head into synchronism and thereafter maintain synchronism.

FUNCTION

If an input to the roller assembly has caused the head to store up a few turns, the action in restoring the matched condition is as follows: The shaft A and the high speed rollers are assumed to be stationary at any position such as shown in Fig. 60A, and the follow-up motor is turning the head in the proper direction to "catch up" to the matched position. The head carries with it the gears and bearings of the transfer mechanism; therefore the low speed roller and intermittent gear D will be carried along until the gear reaches the two teeth on the cam C and goes through a transfer. From previous explanations, it was seen that if the follow-up head were held stationary at this point and the shaft A turned 0.9 revolution, a transfer would take place, moving the low speed roller 45°. Similarly at this point, if input shaft A is stationary and the head is turned 0.9 revolution, the low speed roller will transfer 45° *with respect to its former position in the head*. However, this transfer takes place while the head and roller are still in motion, after which the low speed roller and head travel together but in different relative positions until the next transfer. The roller loses ⅛ revolution in the head at each transfer. Since the 9 to 1 gear reduction mechanism is also traveling with the head, the cam C is traveling in the same direction, Fig. 60B, at a speed of $^8/_9$ that of the intermittent gear and its supports; therefore, it will take nine revolutions of the head in order for the gear D to catch up to the transfer



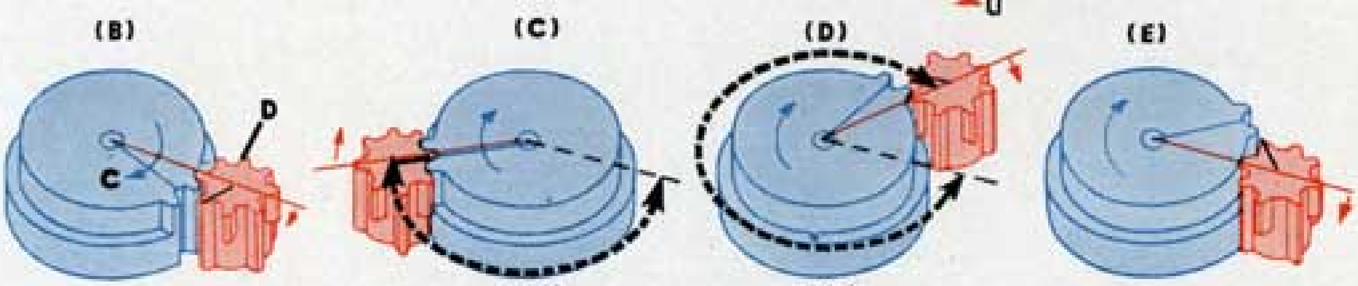


Fig. 60

teeth of cam C and complete another transfer. See Figs. 60B, 60C, 60D, and 60E, Page 63. This sequence of transfers continues until a final transfer brings the low speed roller onto the segment which transfers control to the high speed rollers. The high speed rollers then bring the follow-up head to its matched position and continue to keep it matched.

Mechanical damps (inertia type oscillation damping devices) are employed with the follow-up motors to prevent "hunting" of the system as the matched position is reached. The damp shown in Fig. 61 consists of a flywheel carrying two brake-blocks which contact a disc pinned to the motor shaft. The only connection between the motor and the flywheel is by friction between the brake-blocks and the disc. As the motor tends to accelerate or decelerate, part of the inertia of the flywheel will attempt to prevent speed changes. The amount of flywheel effect may be varied by changing the amount of friction. This is accomplished by turning the adjusting screws which change the compression in the brake-block springs.

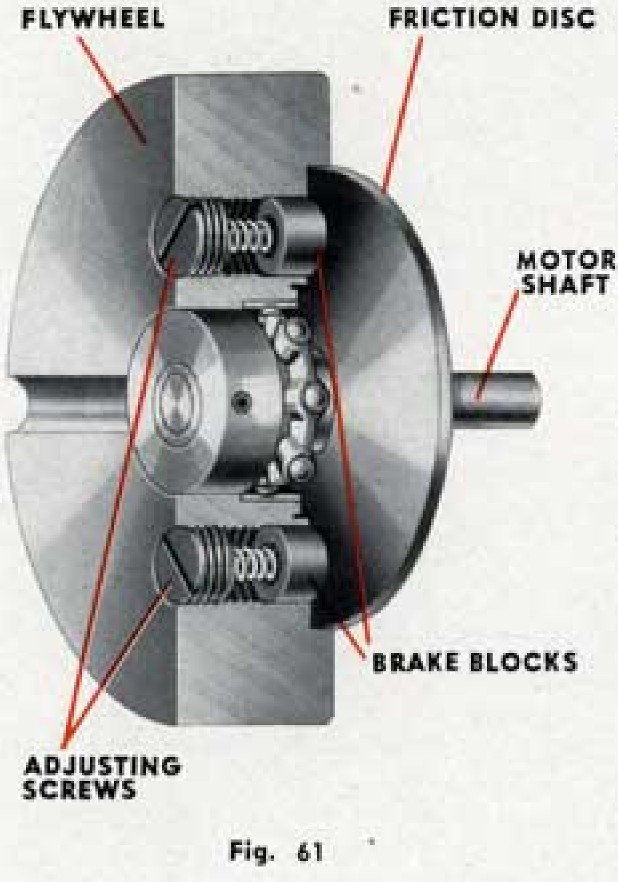


Fig. 61

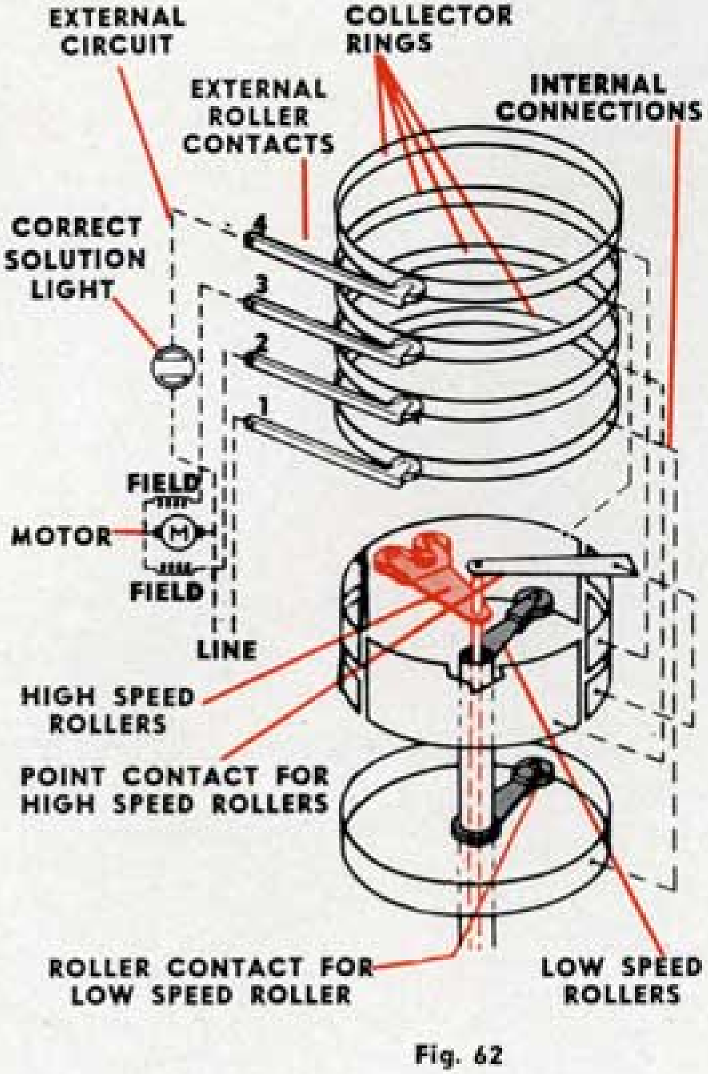


Fig. 62

The spacing of the high speed rollers, with respect to the width of their zero segment, is adjustable, so as to obtain high sensitivity of control at the matched position of the follow-up head. See Page 250. The greater the space between rollers, the less they will have to move in either direction to make contact with a field segment and energize the follow-up motor; hence, the greater the sensitivity. The internal electrical connections of the 4-ring follow-up head are shown in Fig. 62.

Another use of the follow-up head is in conjunction with synchro motors where a quantity is transmitted at two speeds. In this case the high and low speed rollers are driven directly by separate synchro motors and the "transfer" of control is done electrically by means of a 4-ring follow-up head on the low speed synchro.

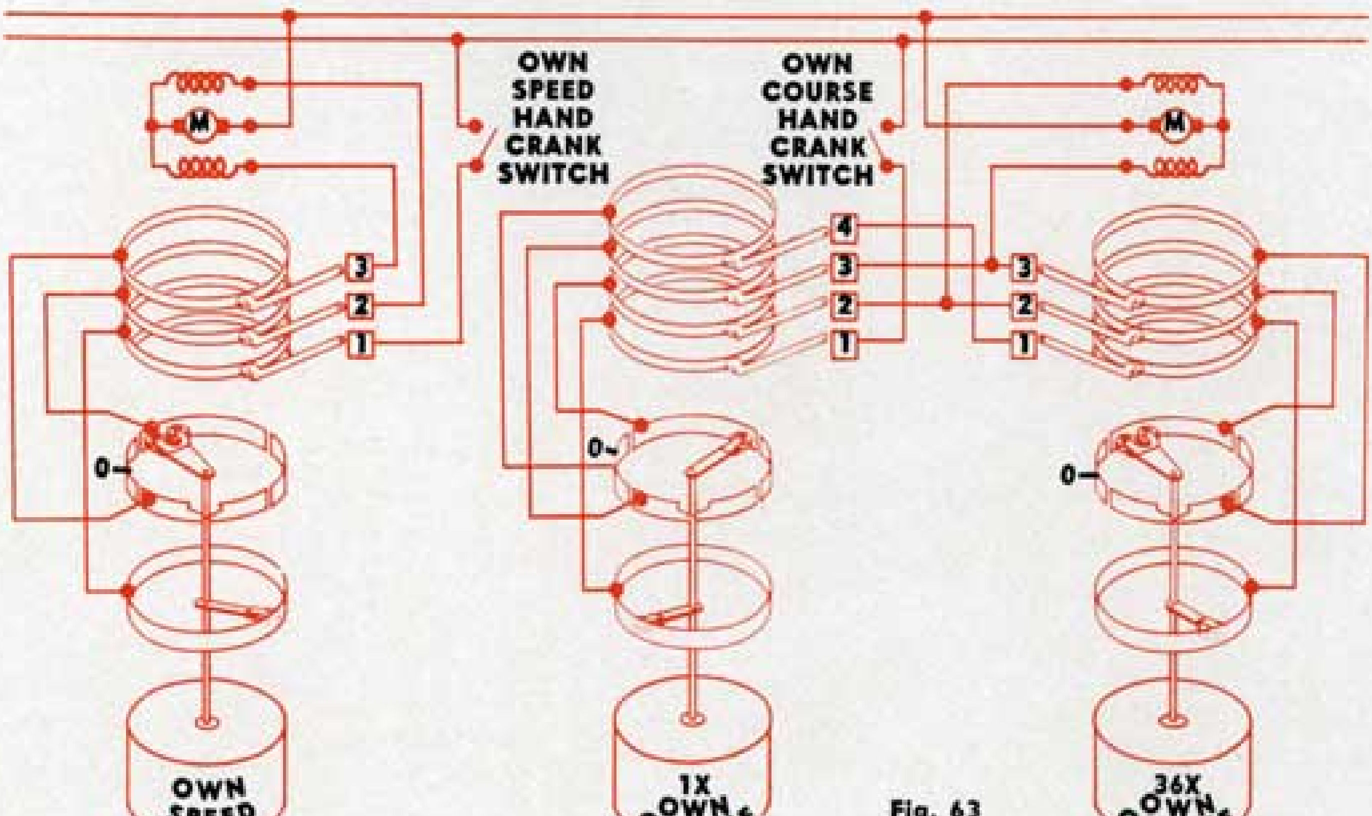


Fig. 63

Fig. 63 shows how the Own Course input is amplified by means of a motor controlled by 1 and 36-speed synchros. In this case the follow-up heads are not equipped with transfer gearing but together are capable of input "storage" by virtue of the electrical "transfer" ratio between high and low speed rollers.

The Own Speed input is also shown in this figure to illustrate the principle of control of a motor by means of a 3-ring non-storing type of follow-up head.

THE INTEGRATOR UNIT

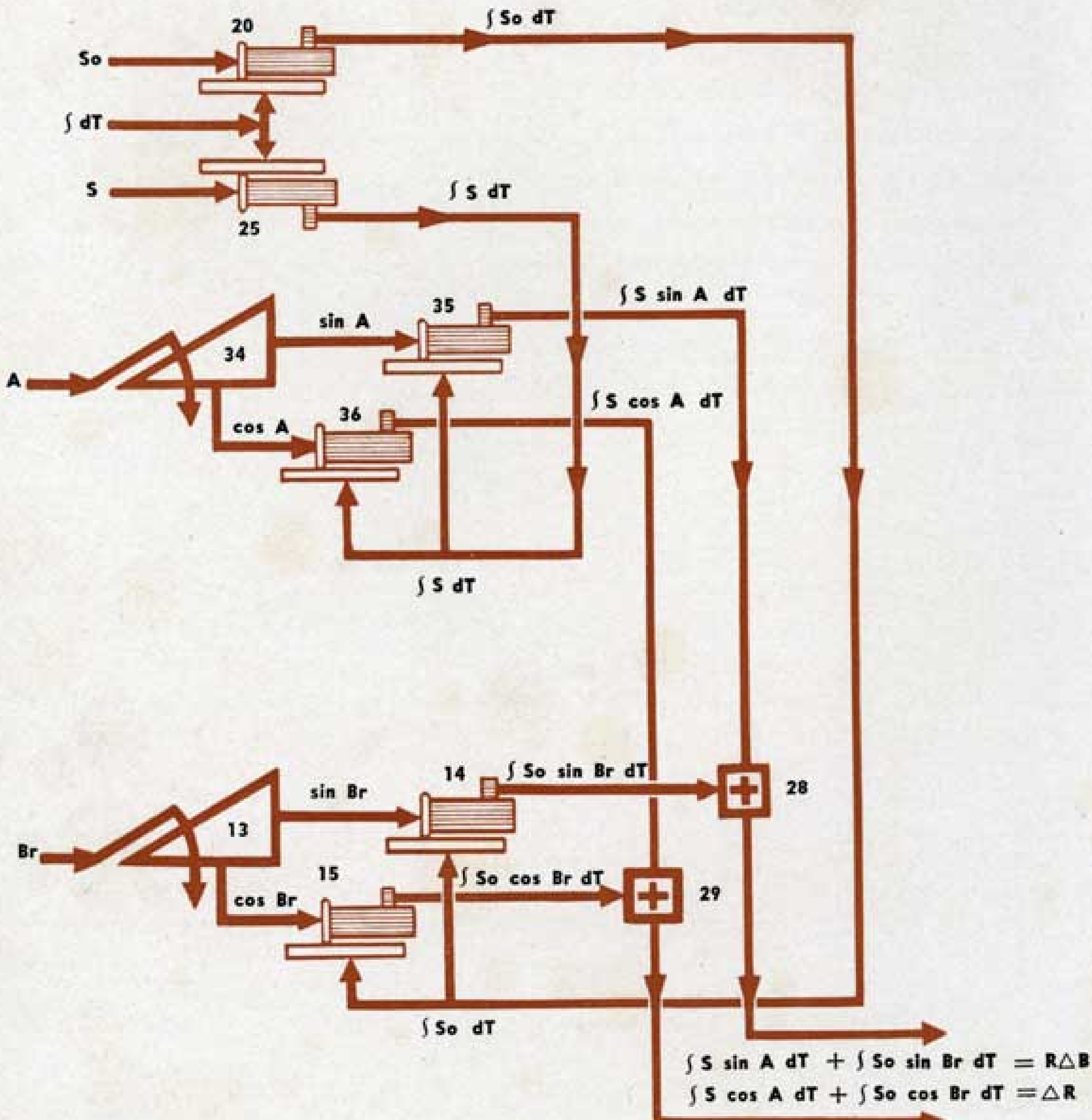


Fig. 64

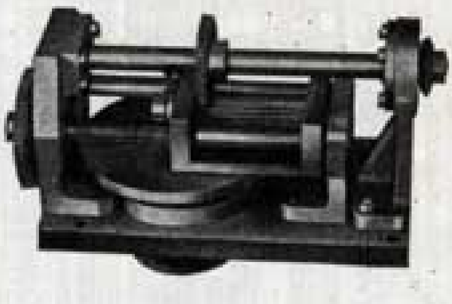


Fig. 65

One of the components of the Position Keeper is the Integrator Unit. The functional diagram of this unit is shown in Fig. 64, Page 66. Values of Own Speed, So, and Target Speed, S, are fed into the Integrators 20 and 25, respectively. In these two mechanisms the increment of Time, dT, is combined with the speeds to form $\int$So dT and $\int$S dT. $\int$So dT is the sum of instantaneous values of So dT and $\int$S dT is the sum of instantaneous values of S dT.

Target Angle, A, is resolved into its components in the Resolver 34 to form sin A and cos A which are sent to the Integrators 35 and 36, respectively. In these mechanisms sin A and cos A are combined with $\int$S dT to form $\int$S sin A dT, and $\int$S cos A dT, respectively.

Relative Target Bearing, Br, is resolved into its components in Resolver 13 to form sin Br and cos Br. These two quantities are in turn sent to the Integrators 14 and 15 where sin Br and cos Br are combined with $\int$So dT to form $\int$So sin Br dT and $\int$So cos Br dT, respectively.

The quantities $\int$S sin A dT and $\int$So sin Br dT are combined in the Differential 28 to form $\int$S sin A dT + $\int$So sin Br dT which equals the sum of instantaneous values of R dB or $\int$R dB. The quantity R dB is very minute and represents an instantaneous change. However, when a measurable period of time is considered, the sum of all the values of R dB equals R$\triangle$B (a total change). Hence, $\int$R dB=R$\triangle$B and Equation IV, Page 25, is solved.

The quantities $\int$S cos A dT and $\int$So cos Br dT are combined in the Differential 29 to form $\int$S cos A dT + $\int$So cos Br dT which equals $\int$dR or $\triangle$R, Equation VIII, Page 25.

THE DIVIDER UNIT

The Divider Unit shown schematically in Fig. 66 consists of an Integrator 46, a Follow-up Head 47 and a Follow-up Motor 48. R dB turns the slip rings of the follow-up head and the quantity R positions the Integrator roller. The follow-up motor is energized by the follow-up head and turns the integrator disc until the trolley assembly of the head reaches the matched position. In order for the follow-up head to be in the matched position, the integrator output must be R dB and the input from the motor is dB. The theory of the integrator is on Page 42.

The sum of the instantaneous values of dB equals $\int$dB or $\triangle$B. $\triangle$B is taken from the motor shaft and used elsewhere in the instrument.

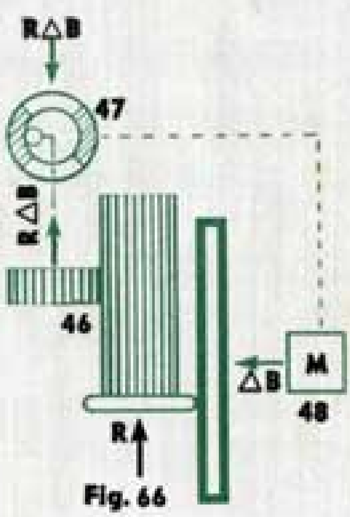


Fig. 66

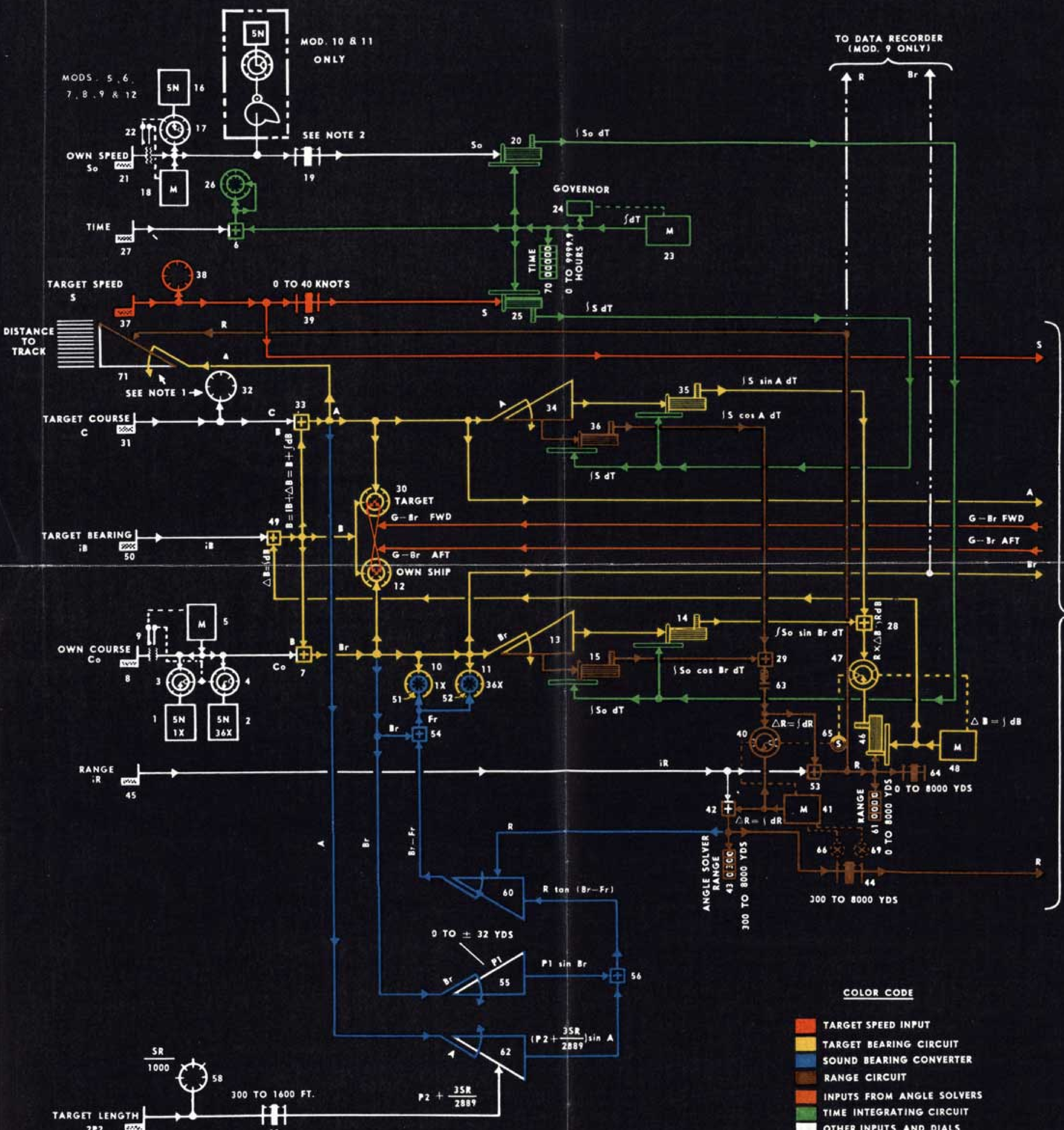
FUNCTIONAL DIAGRAM

OF

POSITION KEEPER

AND SOUND BEARING CONVERTER

FUNCTIONAL DIAGRAM OF POSITION KEEPER AND SOUND BEARING CONVERTER



NOTES:

1. INSTRUMENTS HAVING DISTANCE TO TRACK INDICATOR HAVE NO LOW SPEED TARGET COURSE DIAL
2. OWN SPEED STOP LIMITS ARE AS FOLLOWS:

MOD.	KNOTS
5, 8 & 9	0 TO 25
6, 7 & 12	1 TO 22
10	0 TO 18
11	0 TO 20

FUNCTION

THE POSITION KEEPER

In operating the Position Keeper, estimates of Target Speed, Angle on the Bow and Initial Range, and a measure of Initial Relative Target Bearing are made by observation and introduced into the instrument manually. Own Course and Own Speed are received continuously in the Position Keeper by synchro transmission. A Time Motor will then continuously generate values of Present Range, Relative Target Bearing and Target Angle based upon the inputs. These values are continuously changing with motion of Own Ship and Target, and are continuously indicated on dials on the instrument.

If the initial estimates were correct, new values obtained from a second observation will agree with the values shown on the instrument. If the initial estimates were incorrect a more accurate setting of the Position Keeper may be made based upon new estimates as well as the amount and direction of the error which was found. Subsequent observations will allow still more accurate setting of the instrument, until, finally, further observations will agree with the generated values of the instrument, and show that the Position Keeper is maintaining the position of the Target. The Position Keeper will continue to maintain the position of the Target as long as Target Course and Target Speed do not change. If either Target Course or Target Speed changes, new estimates will have to be introduced and corrected by subsequent observations until the Position Keeper again maintains the position of the Target.

The inter-relation of the generating and associated circuits of the Position Keeper is shown on the functional diagram Fig. 67, Page 68A.

Own Speed, So, is received at 1-speed by synchro transmission on Synchro 16. It is indicated on a dial attached to Follow-up Head 17, and, by means of Follow-up Head 17 and Follow-up Motor 18, positions the roller in Integrator 20. Own Course, Co, is likewise received by synchro transmission at 1 and 36-speed on Synchros 1 and 2. It is indicated on dials attached to Follow-up Heads 3 and 4, and by means of Follow-up Heads 3 and 4 and Follow-up Motor 5 is introduced into Differential 7. When power is turned on, these follow-up motors become energized, and also Time Motor 23. This Time Motor, controlled by Time Motor Governor 24, drives the discs of Integrators 20 and 25 and indicates elapsed Time on Dial 26.

When it is decided to "track" a Target, an estimate of Target Speed, S, is made and introduced into the instrument by turning Handcrank 37 until the value of estimated Target Speed appears on Dial 38. This value of Target Speed positions the roller on Integrator 25 and is also transmitted to the Angle Solver.

Integrator 25 multiplies Target Speed with instantaneous Time producing a value of Target travel. This value rotates the discs of Integrators 35 and 36. Integrator 20 multiplies Own Speed, So, with instantaneous Time and continuously adds these products producing a value of Own Ship's travel. This value rotates the discs of Integrators 14 and 15.

Relative Target Bearing, Br, is measured and the Target Bearing Handcrank, 50, is turned until the measured value of Relative Target Bearing appears on Dials 10 and 11. Initial True Target Bearing, iB, is actually introduced into the instrument and is added to Own Course, Co, by Differential 7 to produce Relative Target Bearing, Br, Equation XI, Page 25. Relative Target Bearing is transmitted to the Angle Solver, the Sound Bearing Converter, and to Dial 12. This value is also resolved into its components by Resolver 13 to produce values of sin Br and cos Br.

Sin Br positions the roller of Integrator 14. Integrator 14 multiplies the instantaneous sine of Relative Target Bearing and instantaneous Own Ship's travel and continuously sums up these instantaneous products, $\int So \sin Br\, dT$, which are fed to Differential 28.

Similarly cos Br positions the roller of Integrator 15. This Integrator multiplies the instantaneous cosine of Relative Target Bearing with instantaneous Own Ship's travel and continuously adds up these instantaneous products, $\int So \cos Br\, dT$, which are fed to Differential 29.

An estimate is made of the Angle on the Bow, Ab. Target Course Handcrank 31 is turned until this estimated value appears on Dial 30. Although Target Course, C, is actually introduced into the instrument it is added to True Target Bearing, B, by Differential 33. The gear mesh of this differential is such that 180° is added to True Target Bearing. This solves Equation XII on Page 25 and produces Target Angle, A. Although Target Angle is produced it is read as Angle on the Bow since Dial 30 is graduated from 0° to 180° port and starboard. Target Angle is transmitted to the Angle Solver, the Sound Bearing Converter and to the Distance to Track Indicator 71.

Target Angle is also resolved into its components by Resolver 34, to produce values of sin A and cos A.

Sin A positions the roller of Integrator 35. This integrator multiplies the instantaneous sin A by instantaneous Target travel and continuously sums up the instantaneous products, $\int S \sin A\, dT$, which are fed to Differential 28. After a finite period of time Differential 28 will have received total values equal to the sum of the instantaneous products.

Similarly cos A positions the roller of Integrator 36. This Integrator multiplies the instantaneous cos A with instantaneous Target travel, and continuously sums up these instantaneous products, $\int S \cos A\, dT$, which are fed to Differential 29. After a finite period of time Differential 29 will have received total values equal to the sum of the instantaneous products.

Differential 29 adds its two inputs solving Equation VIII on Page 25 and producing continuously Change of Range, $\triangle R = \int dR$, which is fed to Differential 53. An initial estimate of Range is made and introduced into the Position Keeper with Range Handcrank 45. Change of Range, $\triangle R$, is continuously added to the initial estimate of Range by Differential 53. Thus, Present Range is continuously maintained and is indicated on Counter 61. This value of Range is transmitted to the Distance to Track Indicator and also positions the roller of Divider Unit 46.

Change of Range also positions Follow-up Head 40 so that Follow-up Motor 41 will produce a value of Change of Range but with amplified power. This value of Change of Range is added to Initial Range by Differential 42. The resultant value Range is indicated on Counter 43, and is continuously transmitted to the Angle Solver and the Sound Bearing Converter.

Differential 28 adds its inputs to solve Equation IV on Page 25 producing $R \triangle B$. This value operates the Follow-up Head 47 and in conjunction with the Range input into the Divider Unit solves Equation X, Page 25 and causes Follow-up Motor 48 to produce a value of Change of True Target Bearing, $\triangle B = \int dB$. Since at each instant dR and R dB are being produced from the instantaneous values of the same fundamental quantities, the only difference being the particular components of these quantities which are used, the R that is introduced into the Divider Unit will always correspond to the instantaneous R dB that is being divided. This Change of True Target

Bearing is added to the initial estimate of True Target Bearing by Differential 49. Thus, the Position Keeper makes use of True Target Bearing which is continuously corrected as it changes due to the motion of Own Ship and Target.

The continuously corrected value of True Target Bearing acts through Differentials 7 and 33 to produce continuously Relative Target Bearing and Target Angle respectively. These values continuously re-enter the generating circuits of the Position Keeper, where they function so as to have incremental changes added to themselves, and to produce the incremental changes in Range. In this manner the position of the Target is continuously maintained.

Corrections made to the original estimates are added in by the various differentials. The respective integrator rollers are re-positioned thus relocating the respective follow-up heads. The follow-up motors quickly match the new values and generation continues. This is equivalent to starting a new problem where the initial inputs differ only slightly from the initial values existing in the instrument.

After the values of S, C, iB, and iR are introduced the Time Dial is turned back to zero by using Handcrank 27 which turns the dial through Differential 6. This allows a continuous log to be kept of the sequence of the steps in the solution. The values of Range and Target Angle operate in the Distance to Track Indicator to indicate continuously the distance from Own Ship to the track of the Target. This indicator operates as the resolver described on Page 47.

Values of Gyro Angle minus Relative Target Bearing, G—Br, from both fwd and aft Angle Solvers are received by Target Dial 30 and Own Ship Dial 12. These values actuate parts of arrows that move relative to the inner parts of these dials.

The outer ring part of Dial 30 receives a value of True Target Bearing but is geared so that when read against the index, it indicates True Target Bearing minus 180° and has no significance as far as the operation of the instrument is concerned. The inner part of Dial 30 receives a value of Target Angle but is graduated so that when read against the index it indicates Angle on the Bow. When the zero of the inner member of Dial 30 is read against the ring dial, Target Course is indicated. When the arrow tails on this dial are read against the inner member, the Track Angles for both fwd and aft torpedoes are indicated.

True Target Bearing is also received by the ring part of Dial 12 and when read

against its index indicates True Target Bearing. The inner member of this dial receives a value of Relative Target Bearing and when read against the index indicates Relative Target Bearing. When the zero of the inner member is read against the outer member Own Course is indicated. Further, when the arrow-heads on this dial are read against the inner member the Gyro Angles for both fwd and aft torpedoes are indicated.

Dial 32 is a high-speed dial indicating a vernier value of Target Course and is only used in testing the instrument.

Handcranks 21 and 8 allow manual input of Own Speed and Own Course in case of failure of their respective follow-up systems. Switches 22 and 9 prevent the possibility of the follow-up motors being energized while the handcranks are engaged.

Own Speed, Target Speed and Range are limited by positive stops to prevent values beyond the limits of the instrument from being introduced with the attendant possibilities of damage. Stop 44 has a lower limit of 300 yards as lesser values are beyond the operational limits of the Sound Bearing Converter and the Angle Solver. Switches 66 and 69 act to de-energize the Change of Range Follow-up Motor 41 when the limits of Stop 44 are encountered.

Signal light 65 is connected between Follow-up Heads 40 and 47 and indicates when the follow-up heads are both synchronized. This is an indication that the Position Keeper has solved the problem based upon the inputs it received and is maintaining this solution. It should here be noted that the light will be extinguished if at short ranges the change in Bearing exceeds the capabilities of the instrument. Further, if the Range decreases below 300 yards as in a collision run by the Target, the light will also go out.

Time Counter 70 indicates the total time that the instrument has been in operation. This time counter is located inside the instrument and is shown in Fig. 96 on Page 105.

The functional diagram, Fig. 67, Page 68A, shows the functions performed by the individual units of which the Position Keeper is comprised. A unit assembly diagram is shown in Fig. 71, Page 78A.

The differences between the various Mods. of the Mk. 3 Data Computer are either differences in terminal tubes, differences in the gearing to Own Speed Integrator or both. The terminal tubes for the various Mods. are shown on the elementary wiring diagram. The differences in gearing to Own Speed Integrator are due to different speeds of transmission of Own Speed from the Ship's Log. That is, differences in the actual number of degrees of rotation of Own Speed Synchro Receiver for a difference of one knot in Own Speed. On the gear diagram, Fig. 68, Page 75A, is a chart of the various

Mods. from Mod. 5 to Mod. 12, indicating the ship to which each Mod. is assigned, the range of the log together with the range of Own Speed Stop, and the number of teeth on the three gears which become affected. The letter "S" after a number indicates that the gear is spirally cut.

The Mk. 3 Mods. 10 and 11 Torpedo Data Computers are used on submarines where the Ship Log transmits Own Speed non-linearly. This means that in going from one speed to another at one part of the Own Speed Dials, the Own Speed Follow-up Motor must make more or less turns than in going from one speed to another at another part of the dial. In order that the Own Speed Follow-up Motor shall position Own Speed Follow-up Head correctly and hence position the roller of Integrator 20 correctly, it is caused to run non-linearly with respect to the angular rotation of the dial by the introduction of a cam. This cam and its attendant gearing are shown on the gear diagram, Fig. 68.

The Mk. 3 Mod. 9 Torpedo Data Computer is used in conjunction with other equipment for instruction purposes only. It operates in an identical manner with the other Mods., but has additional mechanical outputs of Range and Relative Target Bearing which are transmitted to a data recorder. This recorder may be seen on the top of the instrument in Fig. 2, Page 9. The use of this instrument for instruction purposes is beyond the scope of this manual, but will be found in O.D. 2110.

Torpedo Data Computers manufactured at this time are equipped with Distance to Track Indicators. However, instruments now in service will not be changed due to contemplated further modification. These older instruments have in place of the Distance to Track Indicator, a high speed Target Course Dial with a concentric low speed Target Course ring Dial.

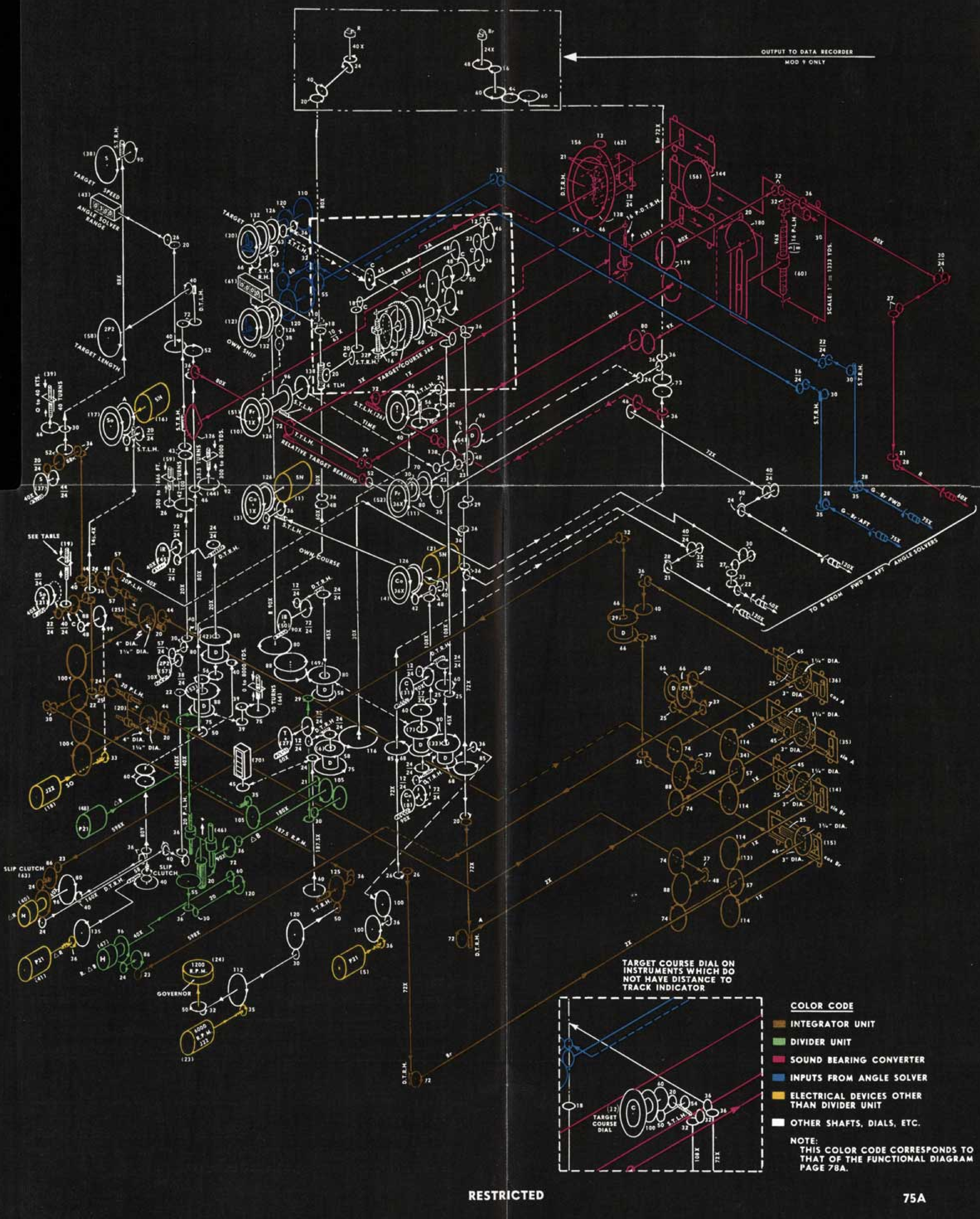
GEAR DIAGRAM

•

OF POSITION KEEPER AND SOUND BEARING CONVERTER

GEAR DIAGRAM OF POSITION KEEPER AND SOUND BEARING CONVERTER

Fig. 68



THE SOUND BEARING CONVERTER

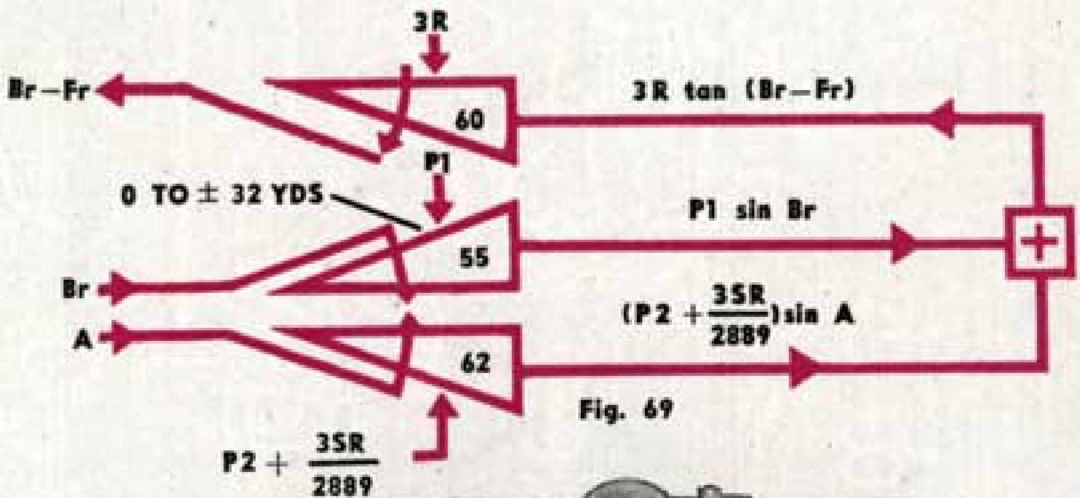


Fig. 69

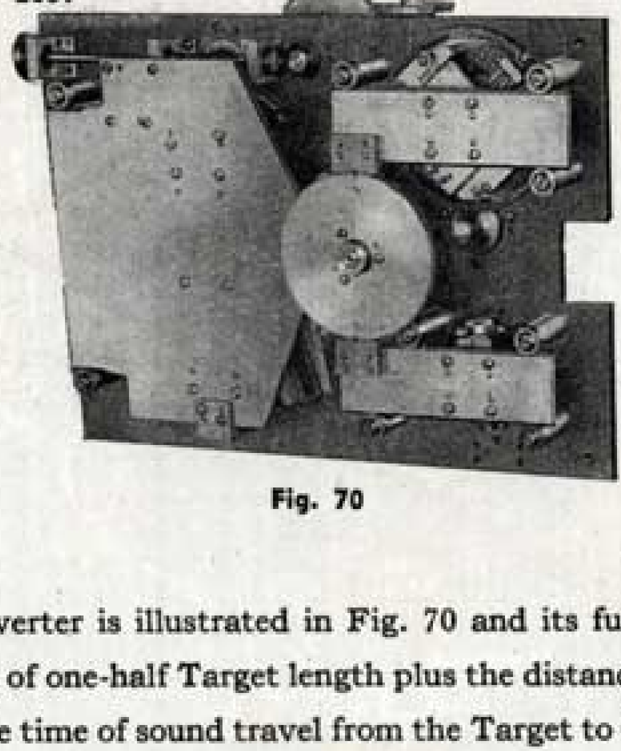


Fig. 70

The Sound Bearing Converter is illustrated in Fig. 70 and its functional diagram is shown in Fig. 69. A value of one-half Target length plus the distance the Target moves along its course during the time of sound travel from the Target to Own Ship is set into the instrument manually. To simplify this procedure, the product of Target Speed and Range as read from the dials of the Position Keeper is divided by 1000. This is a relatively simple calculation. Handcrank 57 is turned until an estimated value of total Target Length, 2P2, is positioned opposite this value of SR/1000, on Dial 58. The dial is so calibrated that the function that is actually introduced into the instrument is P2+3SR/2889.

Target Angle, A, is continuously received from the Position Keeper and is resolved into its components in Resolver 62. The sine component is here multiplied by P2+3SR/2889, thus solving equation XIII on Page 27.

Relative Target Bearing, Br, is also continuously received from the Position Keeper and is resolved into its components in Resolver 55. The sine component is here multiplied by a value of Sound Base Line, P1, which is set into the instrument by a screwdriver adjustment at the time of installation, and Equation XIV on Page 27 is solved. P1 is actually set into the instrument in yards but the gearing is such that the instrument converts it to feet.

The output of Resolver 55 is subtracted from the output of Resolver 62 by Differential 56 and hence Equation XV on Page 27 is solved.

The resulting value 3R tan (Br—Fr) is introduced into Resolver 60. The other input to this Resolver is a continuously received value of Range, introduced in feet. The output of this Resolver is the angle Br—Fr which is the solution of Equation XVI on Page 27. This value is subtracted from a continuously received value of Br by Differential 54 in the Position Keeper. The resulting value of Relative Sound Bearing, Fr, is continuously indicated on the Position Keeper at 1 and 36-speed by Dials 51 and 52 respectively.

These indications have several uses. They assist in obtaining correct estimates for the Position Keeper since the indicated values of Relative Sound Bearing, Fr, should continuously check with the values obtained by the Sound Listening Device. Again, if the Position Keeper has been maintaining the correct position of the Target, and while submerged the indicated values of Relative Sound Bearing begin to deviate from the observed Relative Sound Bearing, it is an indication that Target Speed, Target Course or both have changed, and new values must be introduced into the Position Keeper. Further, it is possible from the Sound Listening Device to obtain estimates of Target Speed as well as changes in Target Speed. Also it can be determined whether the Target is approaching or receding, as well as the rate at which this is happening, thus giving some idea of the value of the Angle on the Bow. This information provides means for manipulating the inputs to the Position Keeper, so as to arrive at values such that the Relative Sound Bearing indication will approach agreement with the observed Relative Sound Bearing of a Target that cannot be seen. Although the values introduced into the Position Keeper by this method may not be very accurate, some idea of the Fire Control Problem that is presenting itself is obtained. Also, the Position Keeper will need but little adjustment should the Target become observable.

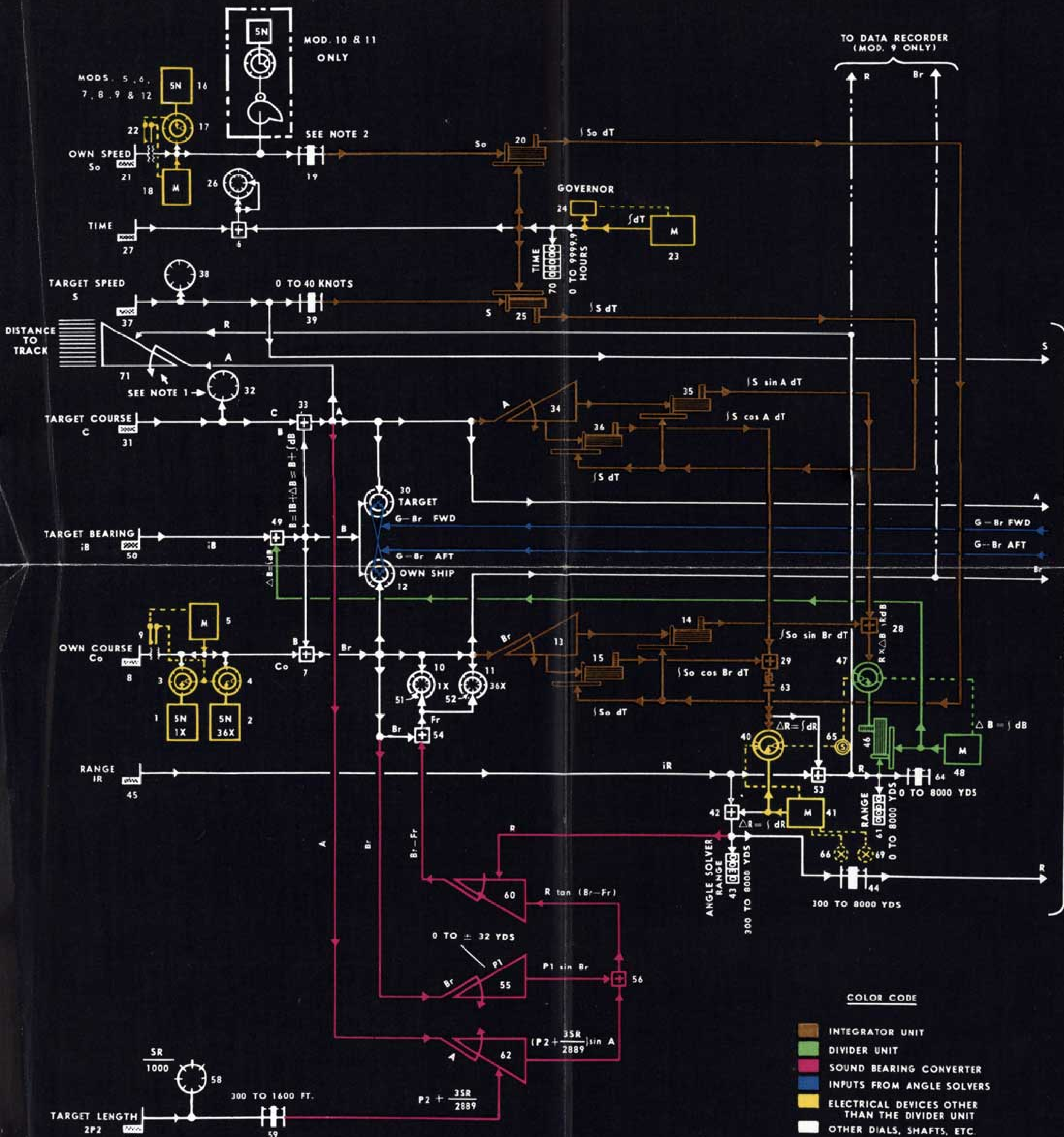
The interrelation of the Sound Bearing Converter and the Position Keeper is shown on the functional diagrams on Pages 68A and 78A.

UNIT ASSEMBLY DIAGRAM OF

•

POSITION KEEPER

AND SOUND BEARING CONVERTER



NOTES:

1. INSTRUMENTS HAVING DISTANCE TO TRACK INDICATOR HAVE NO HIGH SPEED TARGET COURSE DIAL
2. OWN SPEED STOP LIMITS ARE AS FOLLOWS:

MOD.	KNOTS
5, 8 & 9	0 TO 25
6, 7 & 12	1 TO 22
10	0 TO 18
11	0 TO 20

THE RESOLVER UNIT

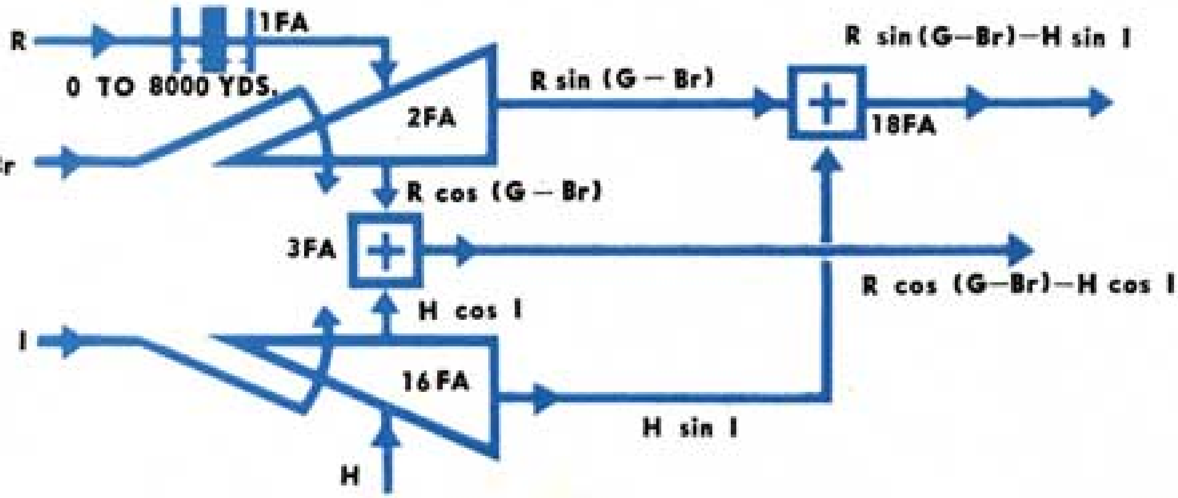


Fig. 72

The Angle Solvers contain several smaller units, one of which is called the Resolver Unit. The Range R, and Gyro Angle minus Relative Target Bearing, G—Br, are sent into the Resolver 2FA and values of R sin(G—Br) and R cos(G—Br) are produced. Range is limited to values between 0 and 8000 yards by the Stop 1FA. A value of Impact Angle, I, from the Differential Unit is sent to the Resolver 16FA where it is combined with Target Run, H, to form values of H sin I and H cos I.

H cos I and R cos (G—Br) are taken from the two resolvers and sent to the Differential 3FA where they combine to form R cos (G—Br)—H cos I. The two resolvers send H sin I and R sin (G—Br) to the Differential 18FA to form R sin (G—Br)—H sin I.

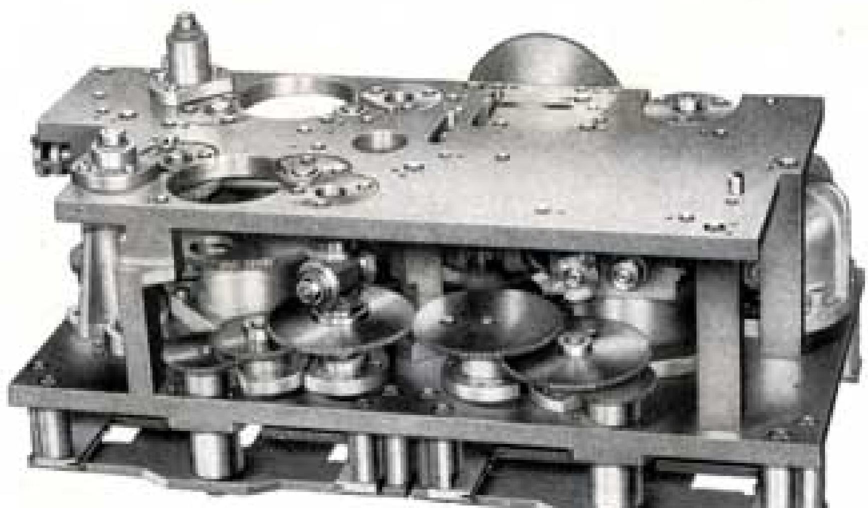


Fig. 73

THE PROPORTIONATOR UNIT

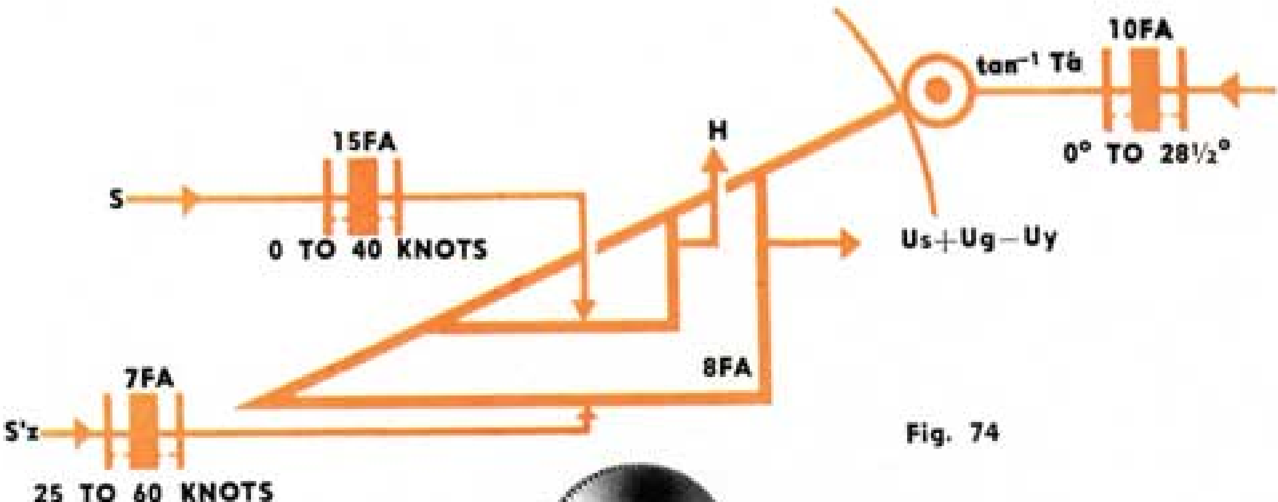


Fig. 74

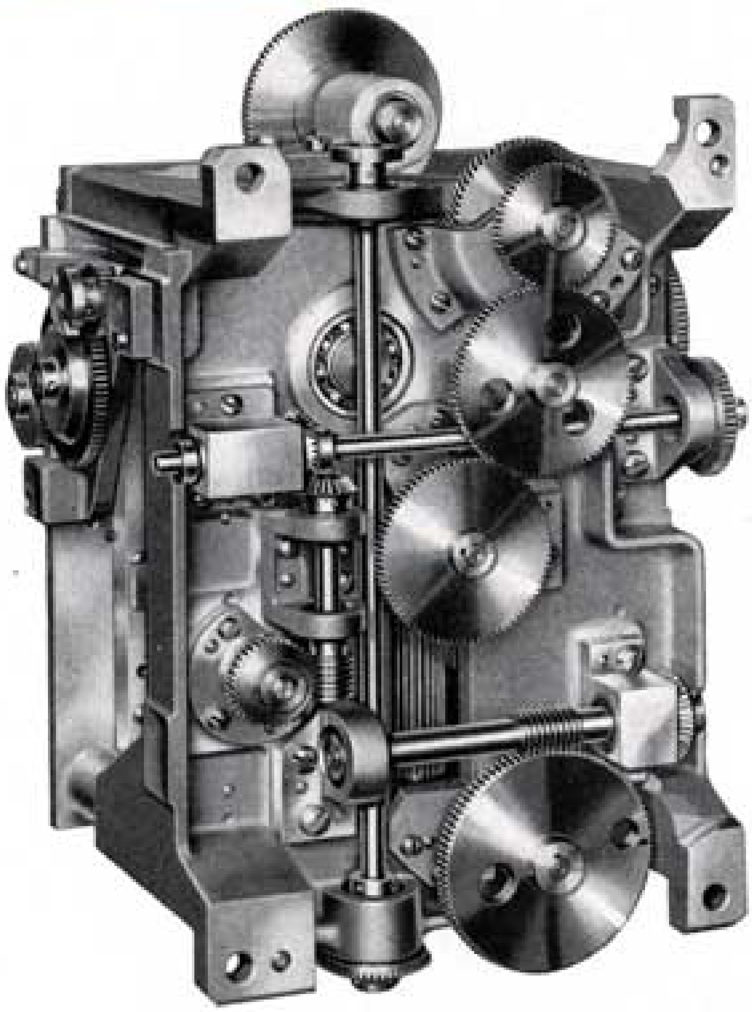


Fig. 75

The Proportionator Unit performs the function of making the ratio between Target Run, H, and Corrected Torpedo Run, Us+Ug−Uy, proportional to the ratio of Target Speed, S, and Corrected Torpedo Speed, S'z. In order to accomplish this function, values of S, S'z, and the angle whose tangent is Corrected Time of Torpedo Run, $\tan^{-1}$ T'a, are used as inputs, and H and Us+Ug−Uy are the outputs.

THE DIFFERENTIAL UNIT

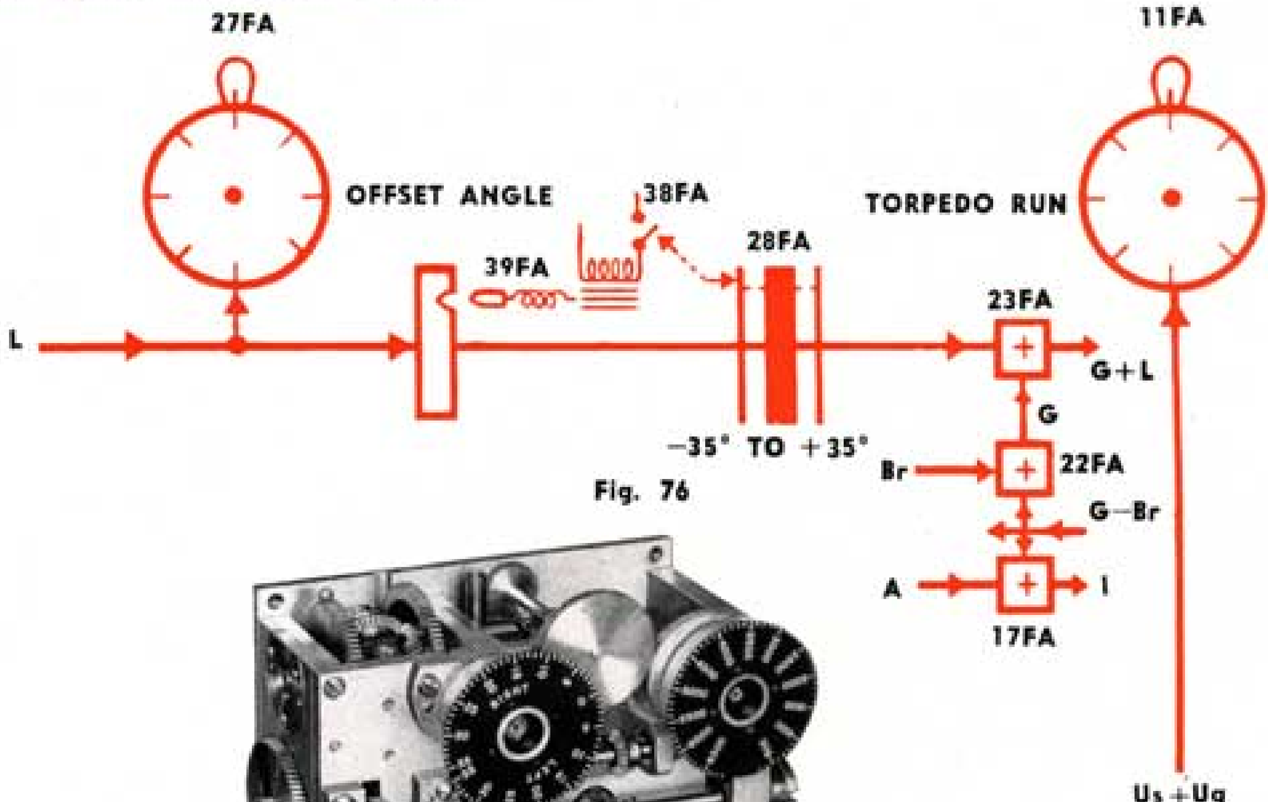


Fig. 76

Fig. 77

A value of Br coming from the Position Keeper enters the Differential 22FA where it combines with the value of G−Br to form G which is sent to Differential 23FA.

The Differential Unit receives a set-in value of Offset Angle, L, as shown on Dial 27FA which combines with the Gyro Angle, G, to produce a value of Gyro Angle Order, G'. When the value of L is zero a detent mechanism holds the setting at this value. The detent mechanism consists of Switch 38FA and Solenoid 39FA which operate to hold the dial at the zero position. However, if it is desired to make some other dial setting, the detent pin can be forced out of its notch by turning Handcrank 26FA, so that Switch 38FA will energize the Solenoid 39FA to pull the pin away from the notch in the gear. A Stop 28FA is provided so that the maximum setting of Offset Angle is equal to plus or minus 35 degrees. L is sent to the Differential 23FA where it is added to G forming a value of Gyro Angle Order, G+L, which equals G'.

A value of A coming from the Position Keeper enters the Differential 17FA where it combines with G−Br to form a value of Impact Angle, I. A value of Torpedo Run, Us+Ug, is shown on Dial 11FA.

THE CAM UNIT

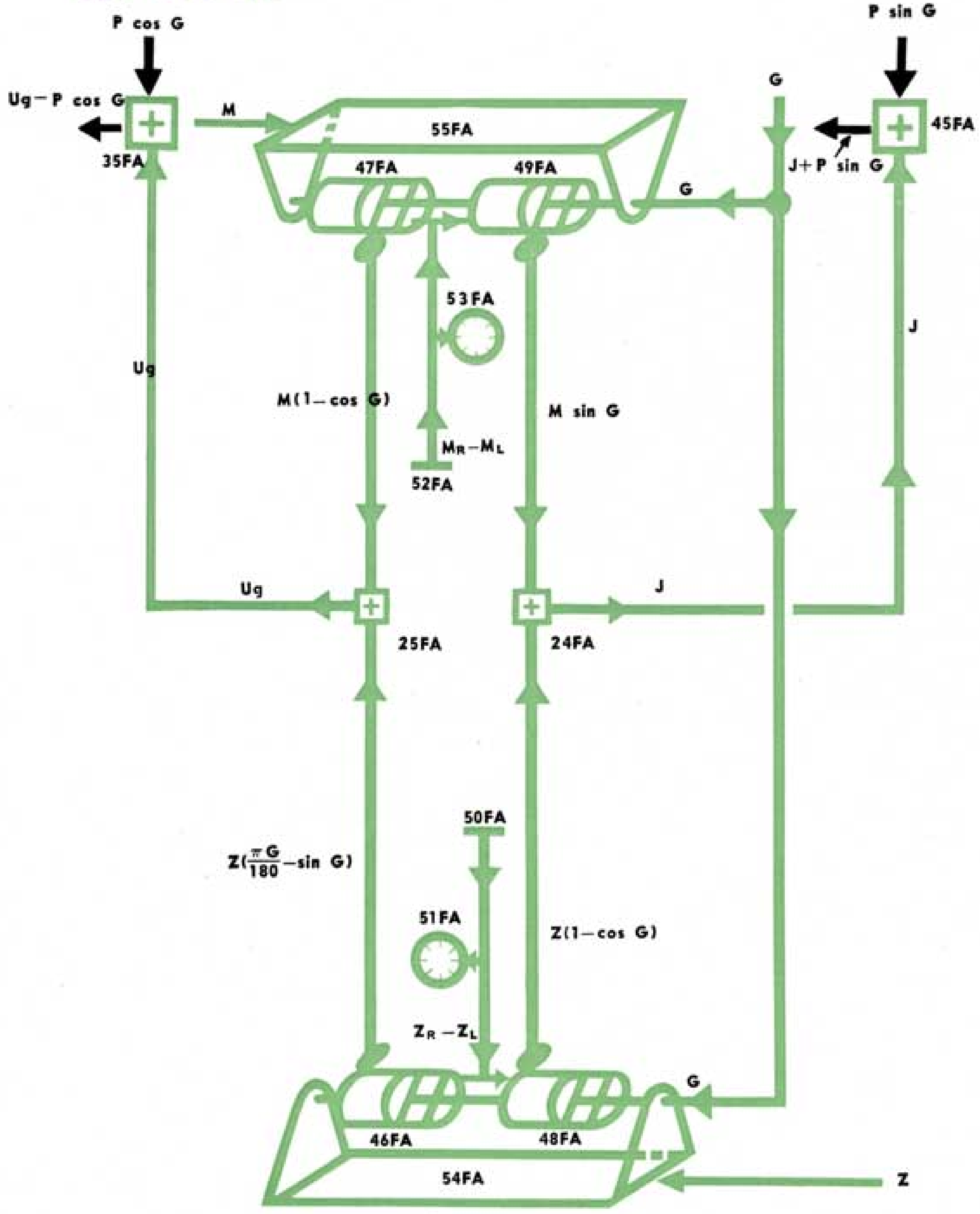


Fig. 78

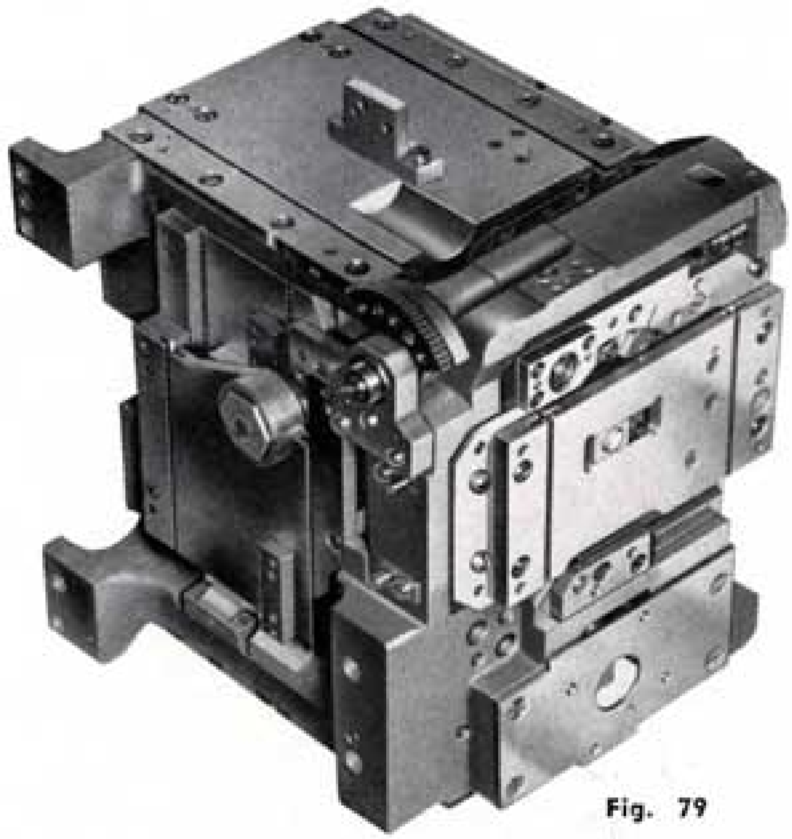


Fig. 79

The Cam Unit produces values of Ug and J from the Torpedo Reach, M, the Torpedo Turning Radius, Z, and the Gyro Angle, G. The value of Right Turning Radius minus Left Turning Radius, $Z_R - Z_L$, is set into the Cams 46FA and 48FA with the Manual Adjustment 50FA and indicated by the Dial 51FA. A value of Z is used to position the Cam Carriage 54FA. The Gyro Angle, G, from the Differential Unit rotates the cams to produce values of $Z(1-\cos G)$ and $Z(\pi G/180-\sin G)$.

Reach for Right Gyro Angles minus Reach for Left Gyro Angles, $M_R - M_L$, is set into the Cams 47FA and 49FA with the Manual Adjustment 52FA and indicated by the Dial 53FA. The cams are positioned by the carriage movement due to the input M. The Gyro Angle,G, is used to rotate the cams to produce values of $M \sin G$ and $M(1-\cos G)$. These latter two quantities are sent to the Differentials 24FA and 25FA respectively.

The Differential 24FA also receives the quantity $Z(1-\cos G)$ which it combines with $M \sin G$ to form the quantity J. $Z(\pi G/180-\sin G)$ and $M(1-\cos G)$ are combined in the Differential 25FA to create a value Ug.

Ug is sent to the Differential 35FA where it combines with a value of $P \cos G$ coming from the Base Line Resolver to form a quantity $Ug - P \cos G$. J is sent to the Differential 45FA where it meets the quantity $P \sin G$ coming from the Base Line Resolver to form a value of $J + P \sin G$.

THE BASE LINE RESOLVER

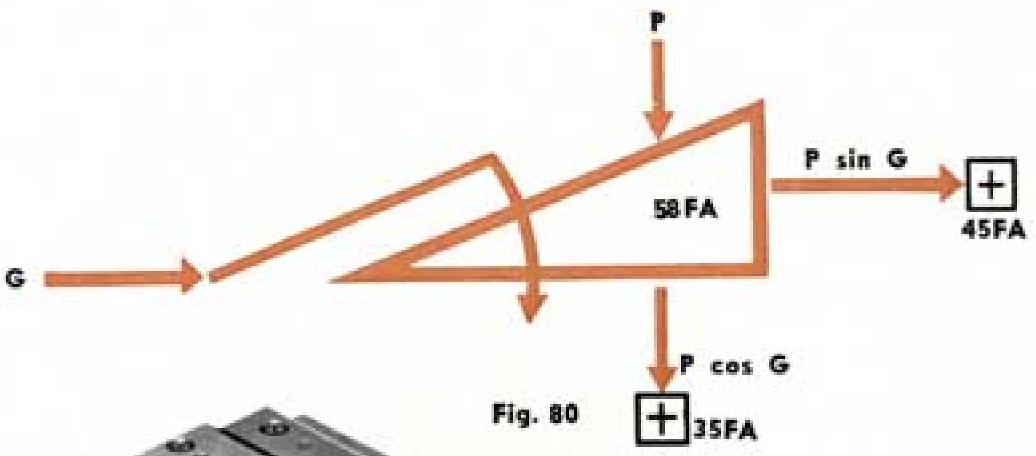


Fig. 80

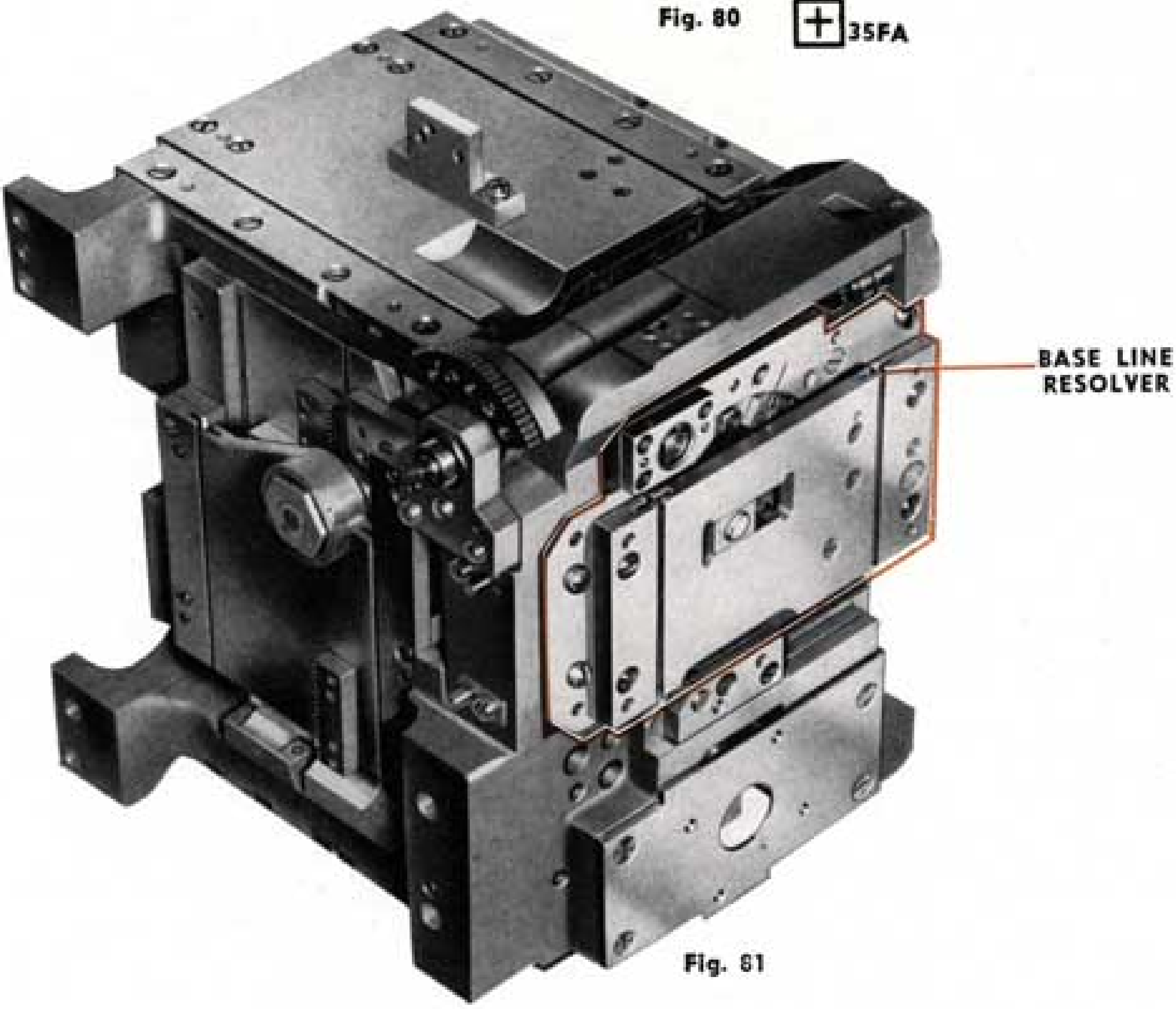


Fig. 81

The Base Line Resolver works in conjunction with the Cam Unit. It receives values of Gyro Angle, G, and Base Line, P, and creates values of P sin G and P cos G. These two values are sent to the Differentials 45FA and 35FA respectively.

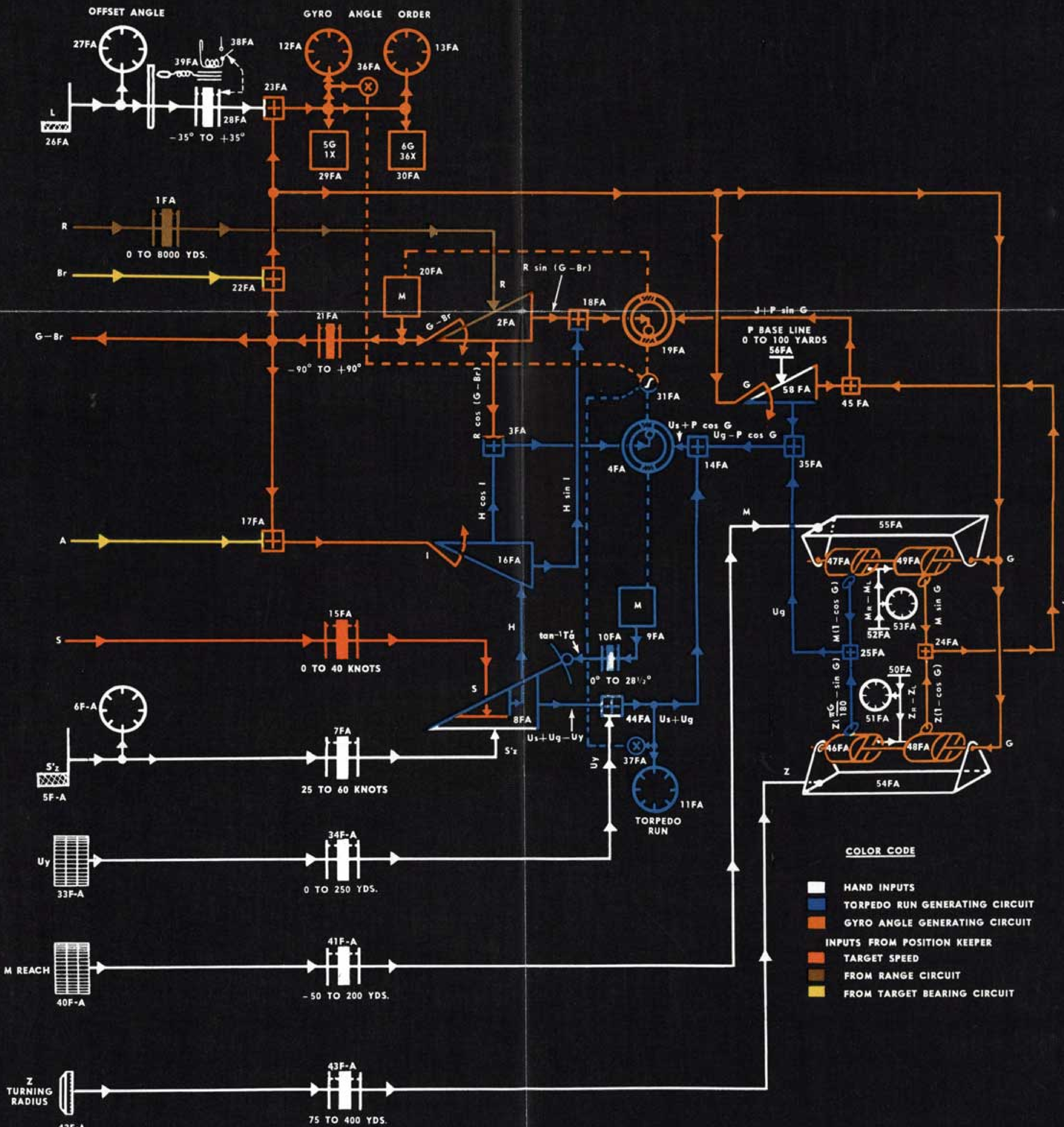
FUNCTIONAL DIAGRAM

OF

ANGLE SOLVER

The fwd and aft Angle Solvers are essentially the same. The letters "FA" after the element numbers indicate that the description applies to either Angle Solver. The letters "F–A" indicate that the element applies to both Angle Solvers simultaneously.

FUNCTIONAL DIAGRAM OF ANGLE SOLVER Fig. 82



FUNCTION

THE ANGLE SOLVERS

The function of the Angle Solver is to produce continuously correct Gyro Angle Orders from the information received from the Position Keeper together with manually set-in values pertaining to the characteristics of the particular torpedo being used. The interrelation of the generating and associated circuits of the Angle Solver are shown on the functional diagram, Fig. 82.

Corrected Torpedo Speed, S'z, is set into the instrument with Depth Set Handcrank 5F–A. Dial 6F–A is made in two parts. A transparent dial is mounted directly over a black opaque dial, and is fastened to it. This transparent dial has a number of sets of graduations for different types of torpedoes. In each set the graduations are from 10 to 50 feet. Handcrank 5F–A is turned until the transparent dial indicates the running depth for which the torpedo has been set, on the set of graduations for the particular torpedo being used. The under dial will then indicate Corrected Torpedo Speed, S'z.

Torpedo Run Difference, Uy, is set in by Handcrank 33F–A. This is a knob dial with several sets of graduations on its periphery. Each set of graduations is from 15 to 120 feet and each set applies to a particular type of torpedo. The knob is turned until keel depth is registered by the graduations for the particular type of torpedo being used. The graduations on the front of the knob will then indicate Torpedo Run Difference, Uy, in yards.

Torpedo Reach, M, is introduced into the instrument with Handcrank 40F–A. This is also a knob dial with several sets of graduations on its periphery for different types of torpedoes. It is turned until the submarine Keel Depth is indicated by the graduations for the particular type of torpedo being used. Graduations on the front of the knob will then indicate Reach, M, in yards.

Values of S'z, Uy, and M, which are set into the instrument make simultaneous corrections for both fwd and aft torpedoes.

Turning Radius, Z, is set in directly in yards with Handcrank 42F–A

and the graduations indicate yards. The differences between the right and left Turning Radii, $Z_R - Z_L$, and the respective Reaches, $M_R - M_L$, for the torpedo being used are set into the Angle Solver at screwdriver Adjustments 51FA and 52FA. In each case the halves of the cams for left values are movable with respect to the halves for right values. If the differences between the right and left values are positive, the cam halves for left values are moved in a decreasing direction. The right cam halves are then set for larger values than the left cam halves. If the differences between the right and left values are negative, the cam halves for left values are moved in an increasing direction. Graduations indicate the values introduced in yards.

The Depth Set Handcrank positions one carriage of the Proportionator. The Torpedo Run Correction is introduced into Differential 44FA. The Reach and Turning Radius Handcranks position their respective carriages in the Cam Unit.

Range, R, is received continuously from the Position Keeper and is introduced into Resolver 2FA. Relative Target Bearing, Br, is also received continuously from the Position Keeper and adds to any existing value of Gyro Angle minus Relative Target Bearing, G−Br, that may exist in the Angle Solver in Differential 22FA. Thus, the output of Differential 22FA is Gyro Angle, G. This value is added to any desired Offset Angle, L, in Differential 23FA and drives Synchro Generators 29FA and 30FA which transmit Gyro Angle Order at 1 and 36 speed to the Gyro Setting Indicator Regulator. These values are indicated on Dials 12FA and 13FA. Gyro Angle, G, is also resolved into its components in Resolver 58FA, and the components are here multiplied by a value of Tube Base Line, P, set in by screwdriver Adjustment 56FA. The outputs of Resolver 58FA are P sin G which is introduced into Differential 45FA, and P cos G which is introduced into Differential 35FA.

The value of Gyro Angle, G, also rotates the Reach, M, and Turning Radius, Z, cams in the Cam Unit. The design of the cams is such that the output of Cam 49FA is M sin G and the output of Cam 48FA is Z (1−cos G). These two values are added in Differential 24FA. Thus, Equation XX on Page 31 is solved, and since M and Z are constant for a particular torpedo, this equation will continuously remain solved as the Gyro Angle changes.

The output of Differential 24FA is Torpedo Advance, J. The value of J is added to P sin G in Differential 45FA and operates Follow-up Head 19FA. If the trolley of the follow-up head is not synchronized, Follow-up Motor 20FA is caused to run. The follow-up motor changes the initial existing value of G—Br. This new value, of course, driving through the circuit just described will re-position the Follow-up Head 19FA. At the same time this value is resolved into its components in Resolver 2FA. The components are here multiplied by Range, R, which is the other input to this resolver. The output R cos (G—Br) is added to values in the Torpedo Run generating circuit by Differential 3FA. The other output R sin (G—Br) has subtracted from it any existing value of H sin I coming from the Torpedo Run generating circuit by Differential 18FA. The output of Differential 18FA positions the trolley of the Follow-up Head 19FA. The follow-up motor will continue to position the trolley while at the same time the follow-up head is being re-positioned, although at a different rate, until the value R sin (G—Br)—H sin I matches the value J+P sin G and Equation XVIII on Page 29 is solved. The follow-up motor will then continue to keep this equation solved as the inputs to the Angle Solver change.

Target Speed, S, is received from the Position Keeper and positions one carriage of the Proportionator Unit, the other input carriage of which has already been positioned by Corrected Torpedo Speed, S'z. Thus, initial values of Target Run, H, and Corrected Torpedo Run, Us+Ug—Uy, are produced and are of such value that the time of Target Run and the Corrected Time of Torpedo Run, T'a, will be equal. The Proportionator Unit maintains the condition of Equation XXII on Page 32. The Torpedo Run Difference, Uy, is subtracted from the Corrected Torpedo Run, Us+Ug—Uy, by Differential 44FA and a value of Torpedo Run, U=Us+Ug, is produced which is indicated on Dial 11FA and also introduced into Differential 14FA.

Again due to the design of the Cam Unit, the output of Cam 47FA is M (1—cos G) and the output of Cam 46FA is Z (πG/180—sin G). These two values are added in Differential 25FA and thus Equation XXI on Page 31 is solved. Again since M and Z are constant for any

given torpedo, this equation will be kept continuously solved as the Gyro Angle changes.

The output of Differential 25FA is Ug. This value is introduced into Differential 35FA where the value P cos G coming from Resolver 58FA is subtracted from it. The output of Differential 35FA, Ug−P cos G, is subtracted from Torpedo Run, Us+Ug, by Differential 14FA. The output of Differential 14FA is then Us+P cos G, and this value positions Follow-up Head 4FA.

Target Angle, A, is continuously received from the Position Keeper and is added to the existing value of G−Br in Differential 17FA producing Impact Angle, I. This solves Equation XIX, Page 29. This angle is resolved into its components in Resolver 16FA and the components are here multiplied by the existing value of Target Run, H. The output of Resolver 16FA, H sin I, is transmitted to the Gyro Angle generating circuit. The other output, H cos I, is added to the value R cos (G−Br) coming from the Gyro Angle generating circuit in Differential 3FA. The output of Differential 3FA, R cos (G−Br)−H cos I, positions the trolley of Follow-up Head 4FA. If the trolley is not in a synchronized position, Follow-up Motor 9FA is caused to run. Follow-up Motor 9FA varies the Angle of the Proportionator Unit and hence the output of the follow-up motor is the angle whose tangent is Corrected Time of Torpedo Run, $\tan^{-1} T'a$.

If the Torpedo Run generating circuit were not affected by the Gyro Angle generating circuit, Follow-up Motor 9FA would quickly find some value of Target Run and Corrected Torpedo Run which would satisfy the existing values of Target Speed and Corrected Torpedo Speed, and existing values of cos I, R cos (G−Br), P cos G, and G, which it receives from the Gyro Angle generating circuit, all of which depend on the existing value of G, and thus would solve Equation XVII on Page 29. In doing so, however, it would have transmitted a value of H sin I to the Gyro Angle generating circuit. The Gyro Angle generating circuit would then transmit new values to the Torpedo Run generating circuit. These values would cause displacement of both the Follow-up Head 4FA and its trolley. Follow-up Motor 9FA would again adjust the Proportionator Unit to keep its equation solved, satisfy the condition for equal time of Target

Run and Corrected Torpedo Run, and at the same time produce a value of H sin I which would allow the Gyro Angle generating circuit to keep its equation satisfied. If with each incremental movement of Follow-up Motor 9FA, the corresponding value of H sin I which is transmitted to the Gyro Angle generating circuit becomes smaller and smaller, Follow-up Motor 9FA will eventually produce the proper angle to satisfy all conditions.

However, the Gyro Angle is constantly changing due to the inputs from the Position Keeper.

For any existing value of Gyro Angle, the Torpedo Run generating circuit will attempt to solve the Equation XVII on Page 29 by producing values of H and Us+Ug−Uy so that the time of Target Run and the Corrected Time of Torpedo Run will be equal. As far as the Gyro Angle generating circuit is concerned, it will attempt to keep Equation XVIII on Page 29 solved producing a value of Gyro Angle which will satisfy the values being received from the Position Keeper as well as the value of H sin I received from the Torpedo Run generating circuit. As the Gyro Angle generating circuit produces different values of Gyro Angle, it transmits new values to the Torpedo Run generating circuit which in turn produces new values of Target Run which will still conform to the condition of Equation XXII on Page 32. It may be that the initial values in the instrument are such that one generating circuit or the other cannot satisfy its own equation without exceeding the limits of its operation. In this case one follow-up motor will run into its Stop and wait for the other generating circuit to change the values so that it can come out of the Stop. As long as all the inputs to the Angle Solver are within the limits of its operation, synchronism will eventually be reached and will continuously be maintained. Mathematically this means that Equations XVII and XVIII on Page 29 and Equation XXII on Page 32 have been solved simultaneously and are continuously kept solved as the factors change. Physically this means that the Time of Target Run and the Corrected Time of Torpedo Run are kept equal, which is a necessary condition for the Target and Torpedo to meet, and that a Gyro Angle is being produced so that the Target and Torpedo will meet on the track of the Target.

When the follow-up heads are both synchronized, the Signal Light,

31FA, which is connected between them, indicates that the correct Gyro Angle is being produced in accordance with the values being received by Angle Solver. Switches 36FA and 37FA open the circuit to the correct solution light if the Gyro Angle or Torpedo Run values exceed the limits of the instrument.

If it is desired to add or subtract from the Gyro Angle in order that several torpedoes fired in succession may spread, an Offset Angle may be introduced with Handcrank 26FA and the amount of this offset will be indicated on Dial 27FA. This value is added to the correct Gyro Angle Order in Differential 23FA and the combined quantity turns the Gyro Angle Order Synchro Generators. The detent and switch mechanism is explained on Page 126.

Numerous Stops are shown in the functional diagram which prevent values beyond the capability of the Angle Solver from being introduced.

The value, G—Br, is transmitted to the Position Keeper.

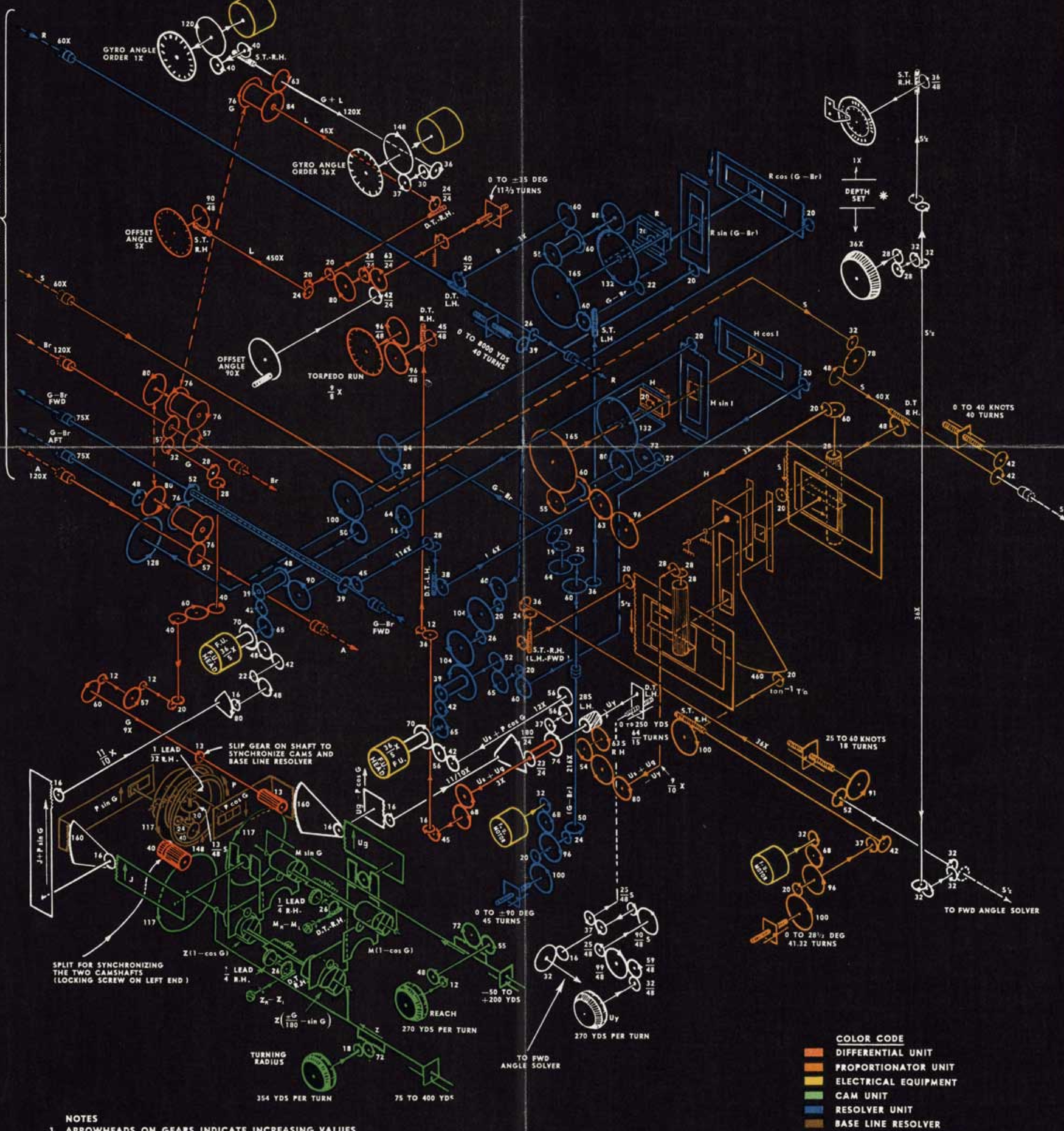
The functional diagram, Page 95A, shows the functions performed by the individual units of which the Angle Solvers are comprised.

GEAR DIAGRAM

OF

AFT ANGLE SOLVER

GEAR DIAGRAM OF ANGLE SOLVER Fig. 83



COLOR CODE

- DIFFERENTIAL UNIT
- PROPORTIONATOR UNIT
- ELECTRICAL EQUIPMENT
- CAM UNIT
- RESOLVER UNIT
- BASE LINE RESOLVER
- CONNECTING SHAFTING AND OTHER CHASSIS UNIT

NOTE: THIS COLOR CODE CORRESPONDS TO THAT OF THE FUNCTIONAL DIAGRAM, PAGE 95 A.

NOTES

1. ARROWHEADS ON GEARS INDICATE INCREASING VALUES IN A POSITIVE SENSE.
2. ARROWHEADS ON SHAFTS INDICATE FLOW OF THE FUNCTIONS.
3. ALL GEARS ARE 32 PITCH EXCEPT AS INDICATED.
4. FWD. ANGLE SOLVER ESSENTIALLY THE SAME AS AFT.
5. FOR ANGLE SHAFTS 1X = 1 TURN/360°
6. FOR RANGE (RUN) SHAFTS 1X = TURN/8000 YDS.
7. FOR SPEED SHAFTS 1X = 1 TURN/40 KNOTS.
8. INCREASING VALUE OF DEPTH SET GIVE DECREASING VALUES OF TORPEDO SPEED.
9. INCREASING VALUES OF Uy GIVE DECREASING VALUES OF TORPEDO RUN.

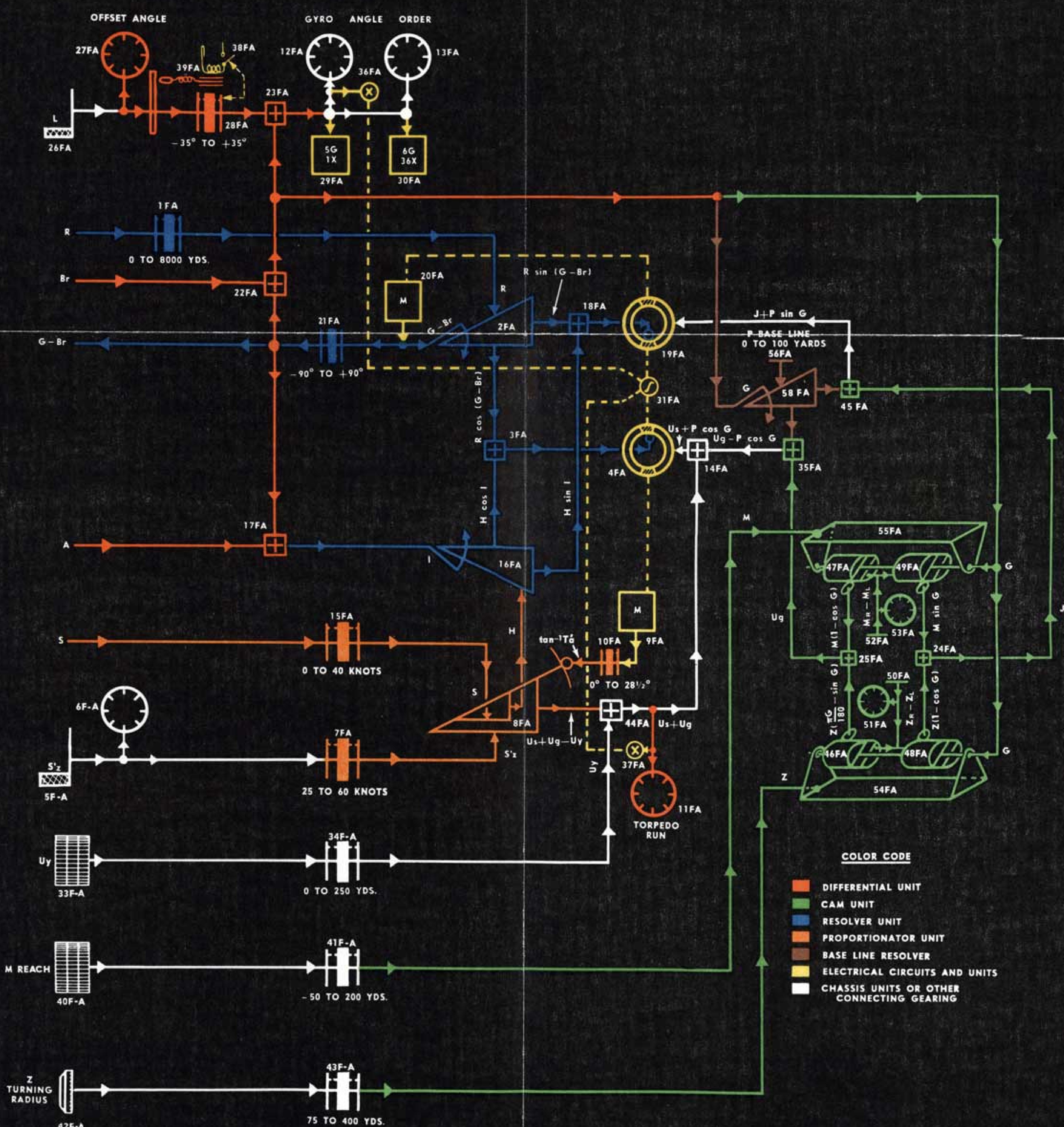
UNIT ASSEMBLY DIAGRAM

OF

ANGLE SOLVER

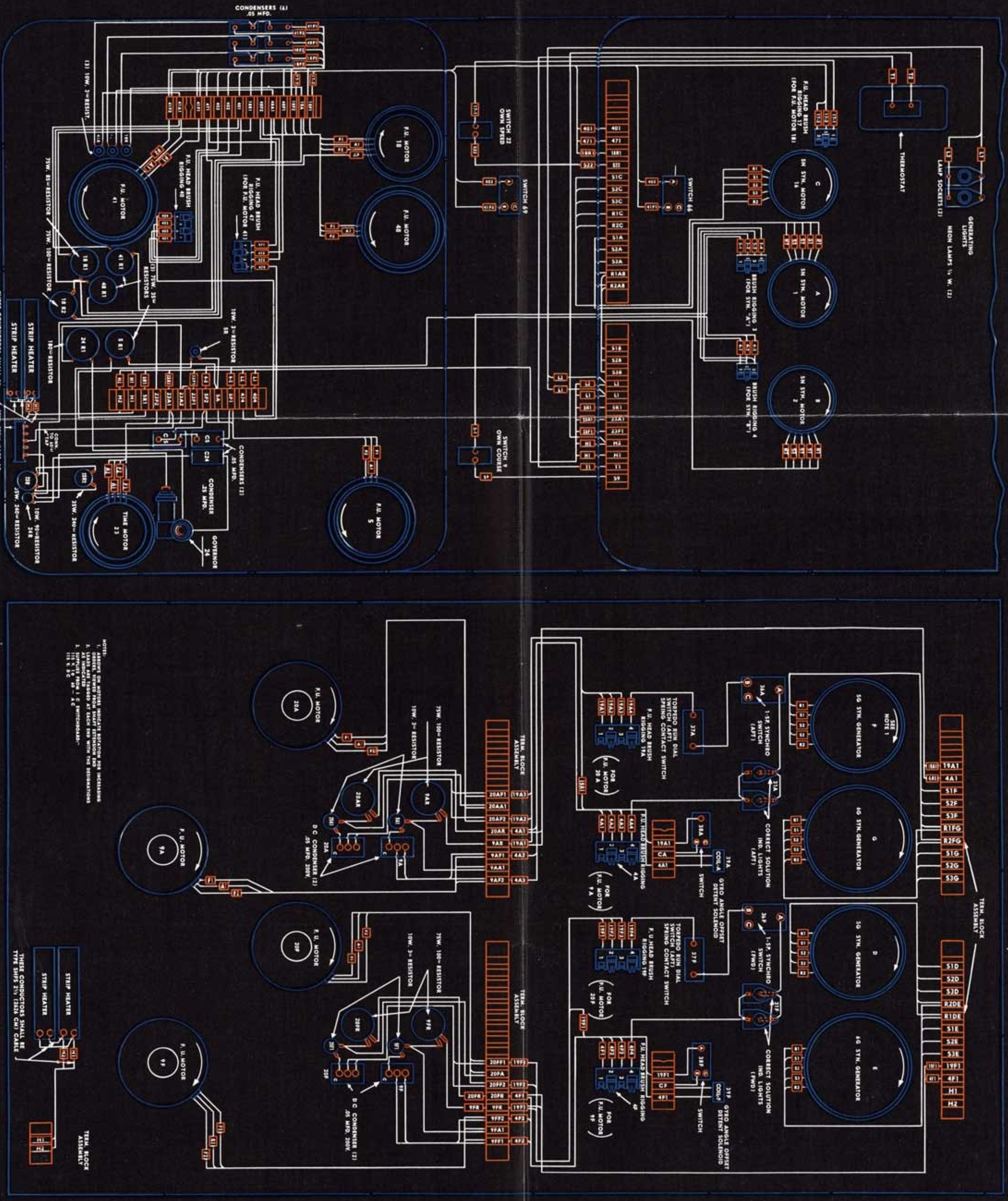
UNIT ASSEMBLY DIAGRAM OF ANGLE SOLVER

Fig. 84



This page is blank.

INTERNAL WIRING DIAGRAM OF POSITION KEEPER AND ANGLE SOLVERS



CONSTRUCTION

This section deals with the general mechanical construction of the Torpedo Data Computer and its component parts, with only such functional description as is necessary to support the description. For further details as to function refer to the section on Function. Likewise, further details of construction may be found in the section on Disassembly.

SECTION 4

GENERAL

The instrument consists of two aluminum castings which are weatherproof and which are secured together so as to function as a single unit.

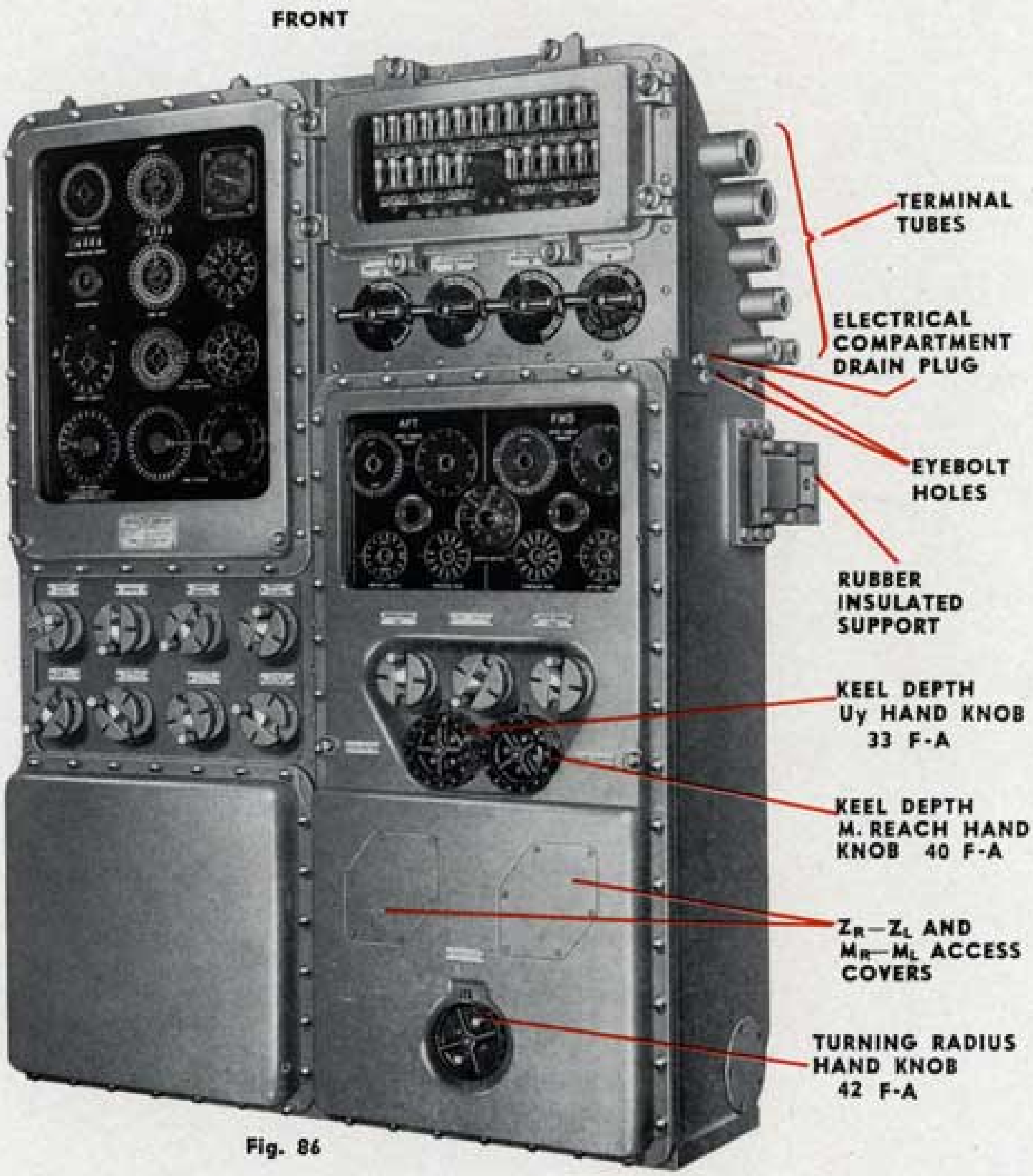


Fig. 86

Referring to the various illustrations of this section on Construction, the following external features may be located:

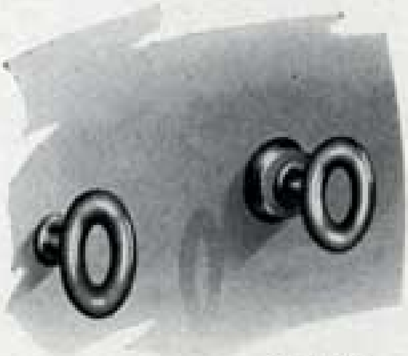


Fig. 87

Eyebolt holes, provided for installation or other lifting purposes.

Heater unit, for keeping the Angle Solver at a constant temperature.

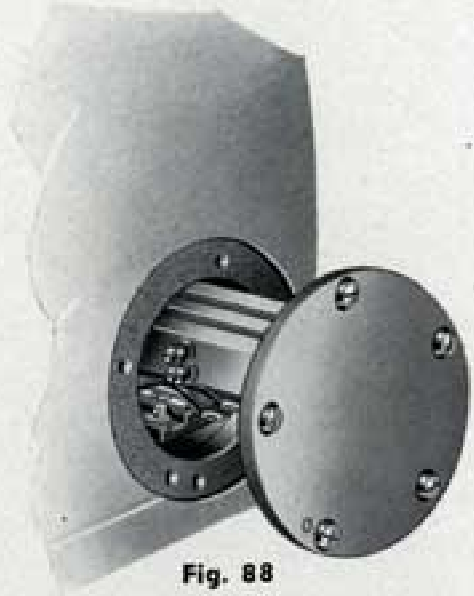


Fig. 88

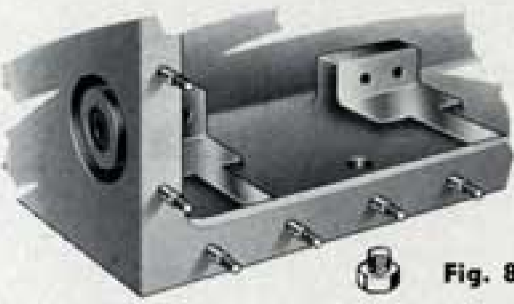


Fig. 89

Three drain plugs, one in the bottom of each main casting and one in the side of the electrical compartment, which is a separately walled-off compartment.

Mountings, rubber insulated, which support the weight of the instrument.

Fig. 90

Fig. 91

Supports, rubber insulated, one on each side bolted to the hull of the ship.

Terminal tubes, by which all external wiring is led into the instrument.

Fig. 92

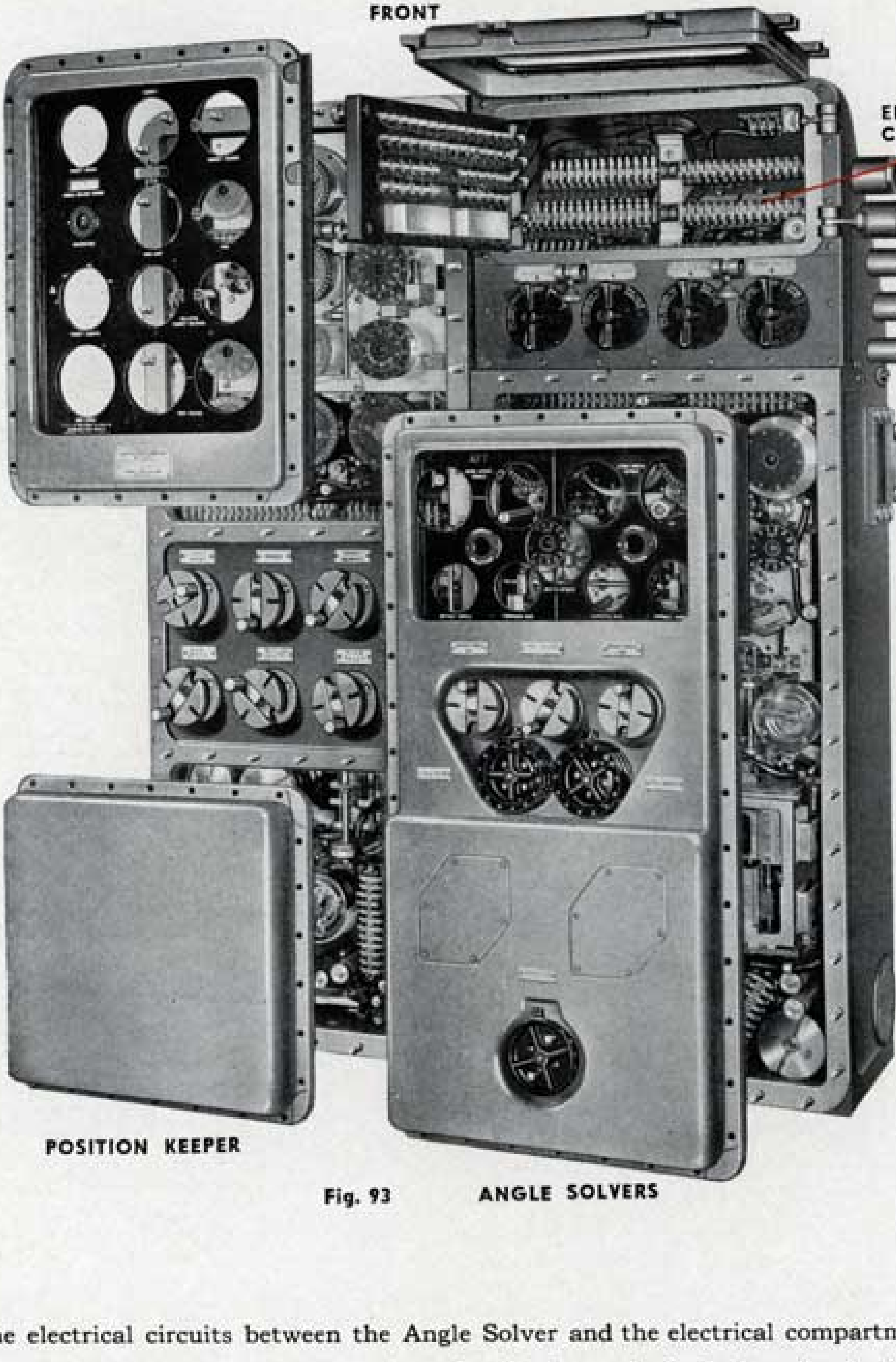


Fig. 93

The electrical circuits between the Angle Solver and the electrical compartment are completed by a cable which passes through a single terminal tube into the Angle Solver compartment from whence it is distributed to the various units in the two sections.

CONSTRUCTION

The two sections are securely bolted together with five bolts and aligned by means of two large dowel pins. In addition, a long plate secures the two sections along their

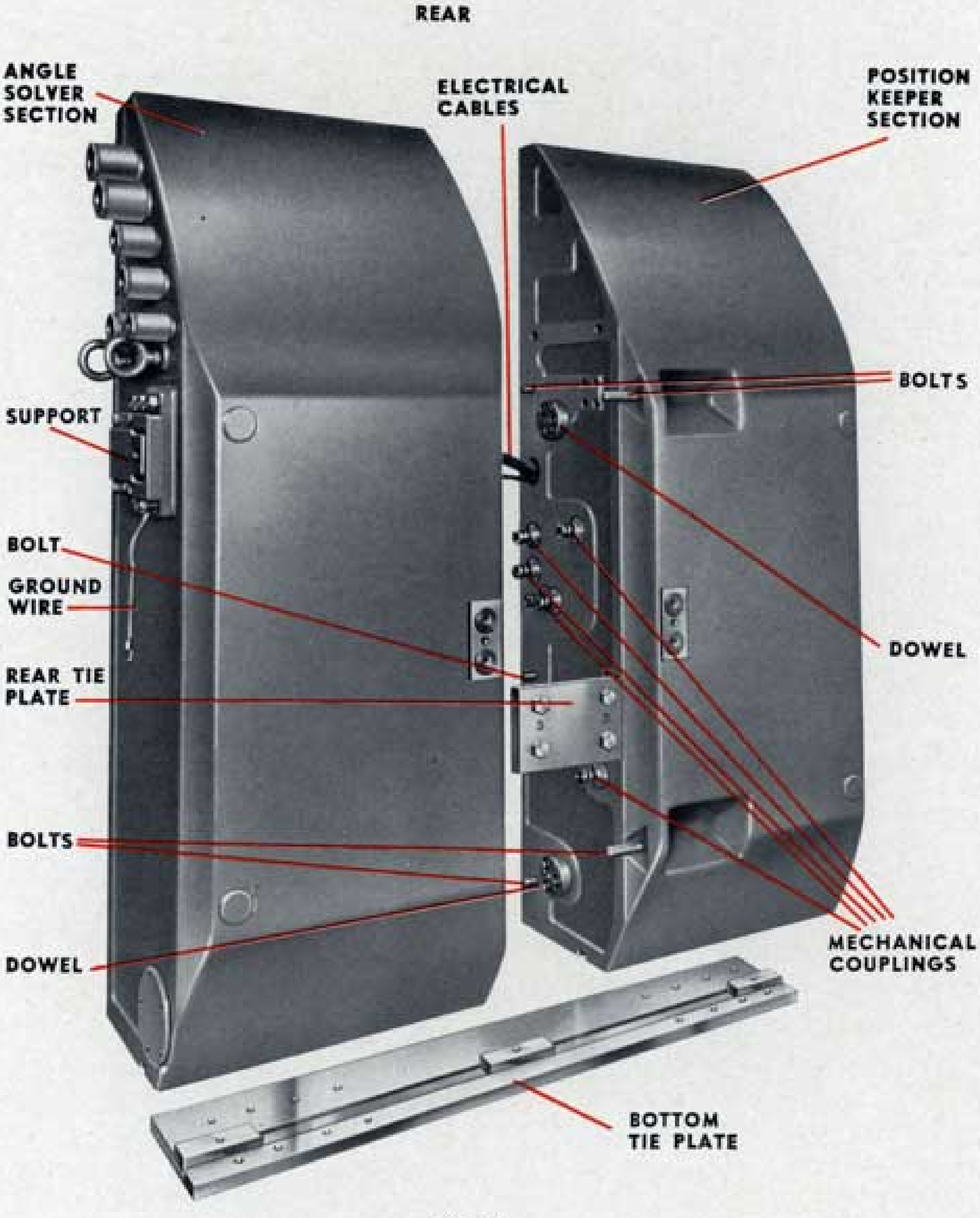


Fig. 94

bottom surfaces, and another plate is bolted across the back surfaces of the two sections. Shafting and cabling are led from one section to the other through holes provided for that purpose in the two sides which are adjacent when bolted together.

POSITION KEEPER SECTION

EXTERIOR

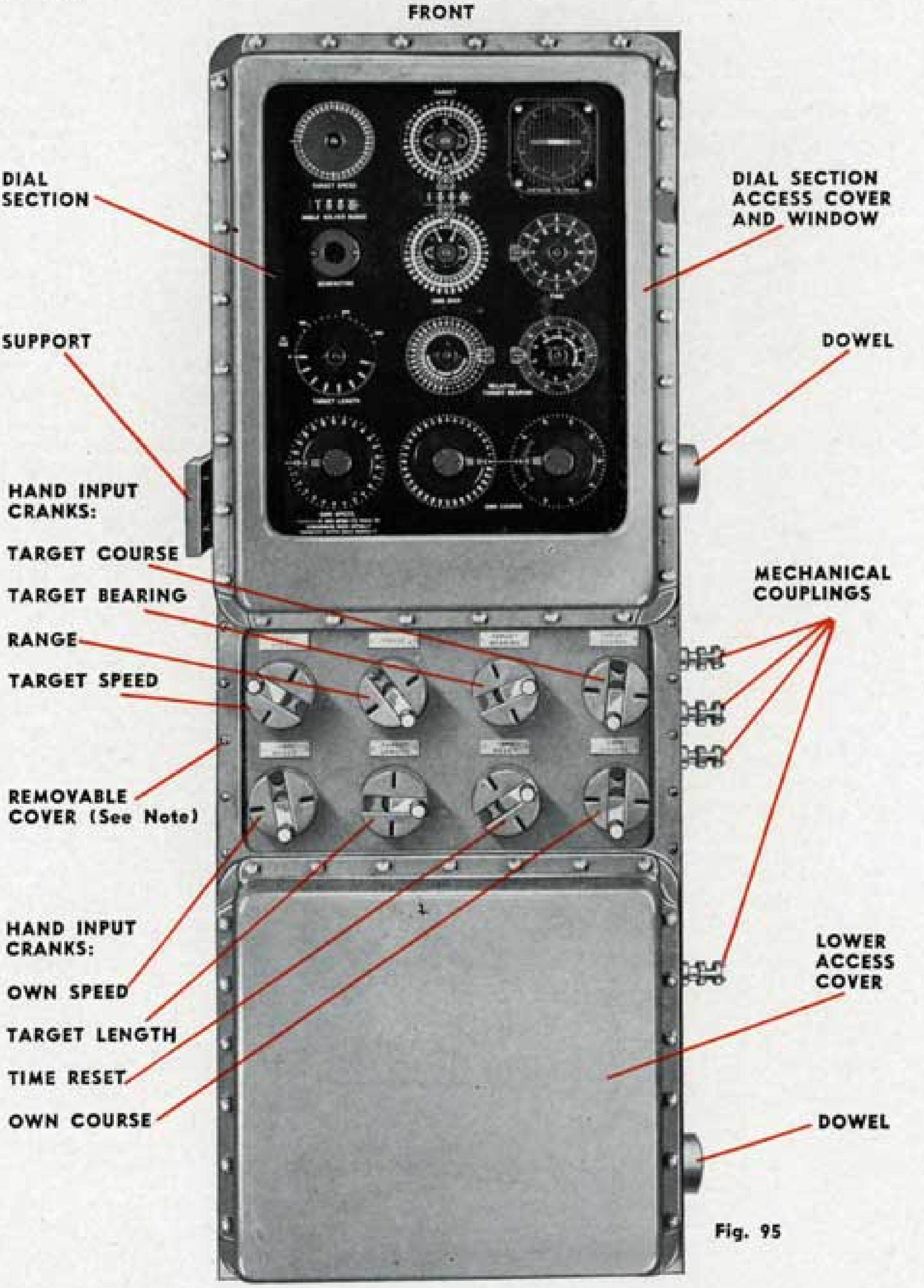


Fig. 95

*NOTE: This cover (together with the hand input cranks) may be removed, but only after removal of both the other covers on this section.

INTERIOR

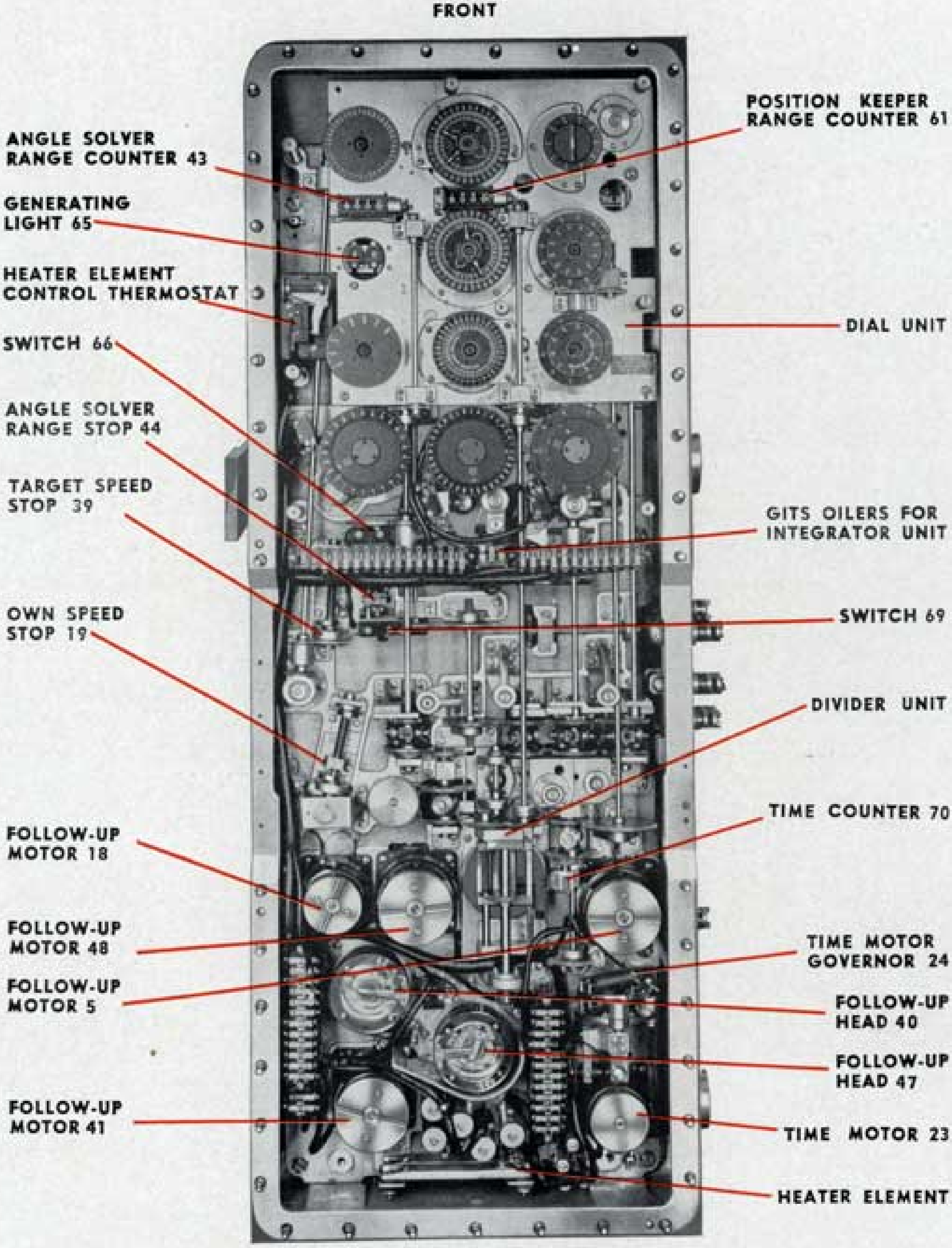


Fig. 96

All of the space within the left hand section is occupied by the Position Keeper mechanism and Sound Bearing Converter. All units of this section are mounted on an aluminum chassis.

POSITION KEEPER CHASSIS

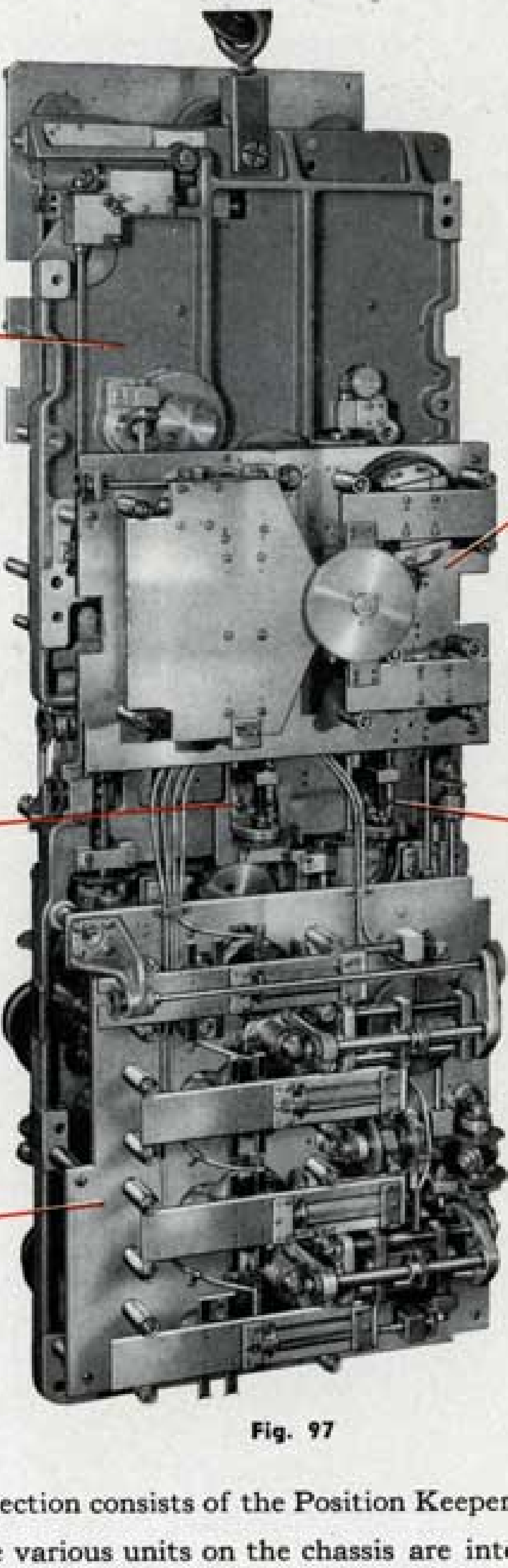


Fig. 97

The mechanism in this section consists of the Position Keeper and its associated Sound Bearing Converter. The various units on the chassis are interconnected by means of shafting and gearing, as can be better seen during disassembly. It conforms to the gear diagram on Page 75A of this manual.

DIALS

These dials are located in the upper front portion of the Position Keeper section.

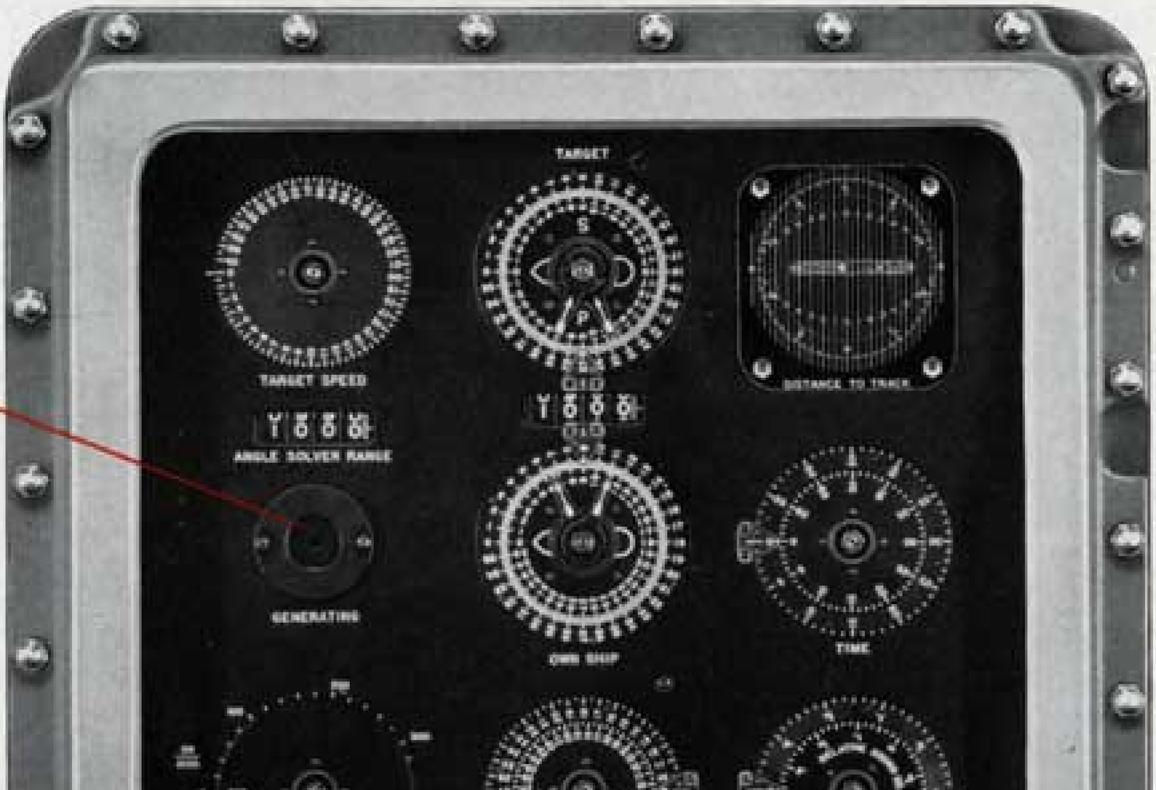


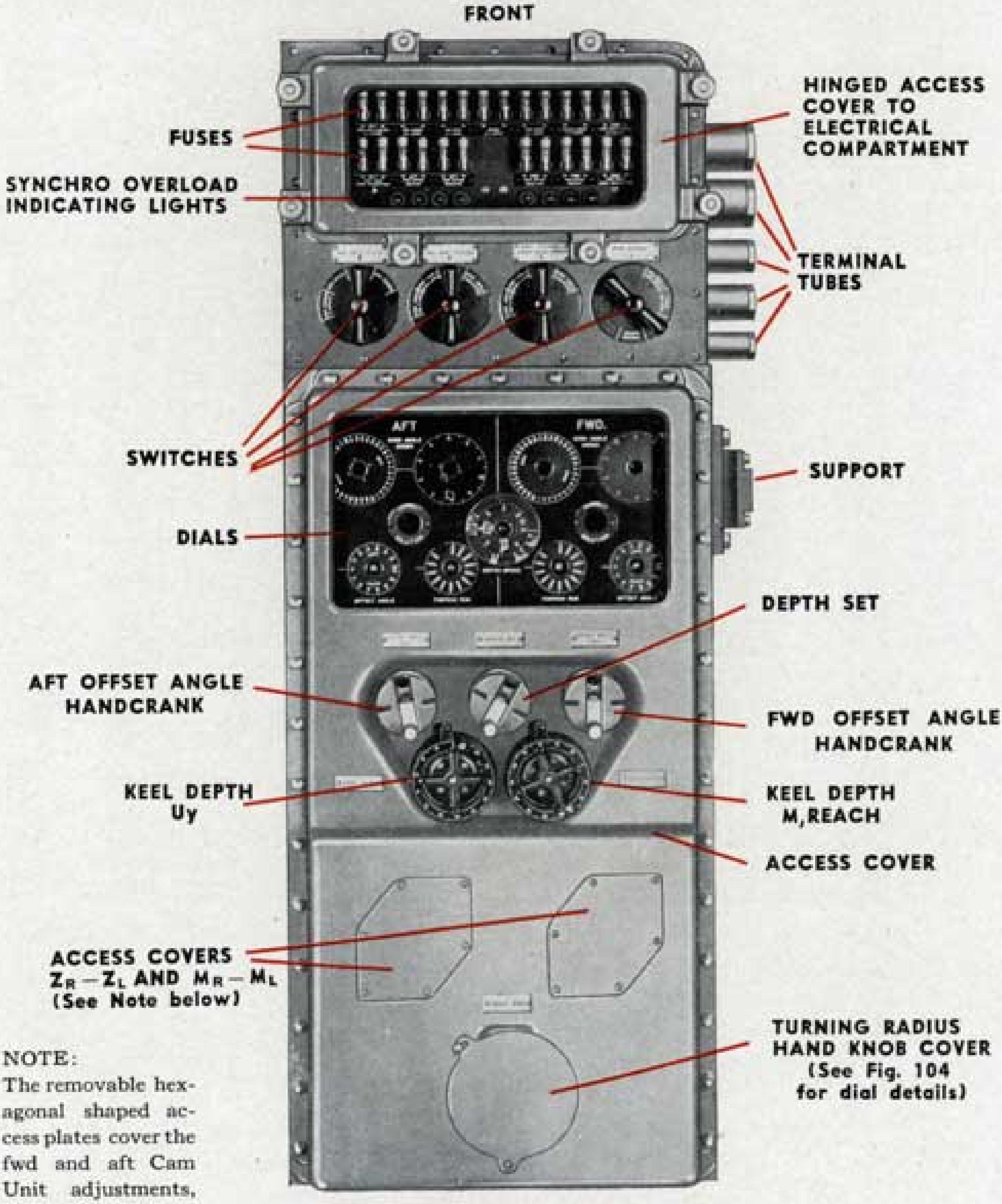
Fig. 98

NOTE: This light glows when the Position Keeper is in synchronous operation.

ANGLE SOLVER SECTION

EXTERIOR

The lower front plate of the Angle Solver Unit is removable for access to the Angle Solver mechanism. Under the lower glass window are the dials, one set for fwd and one set for aft control indications. They are shown in Fig. 102, Page 111.



NOTE:
The removable hexagonal shaped access plates cover the fwd and aft Cam Unit adjustments, which are set according to the type of torpedo being used.

Fig. 99

INTERIOR

The two Angle Solvers are located in this section. The aft unit is on the left and the fwd unit is on the right. Illustrated with dial plate off.

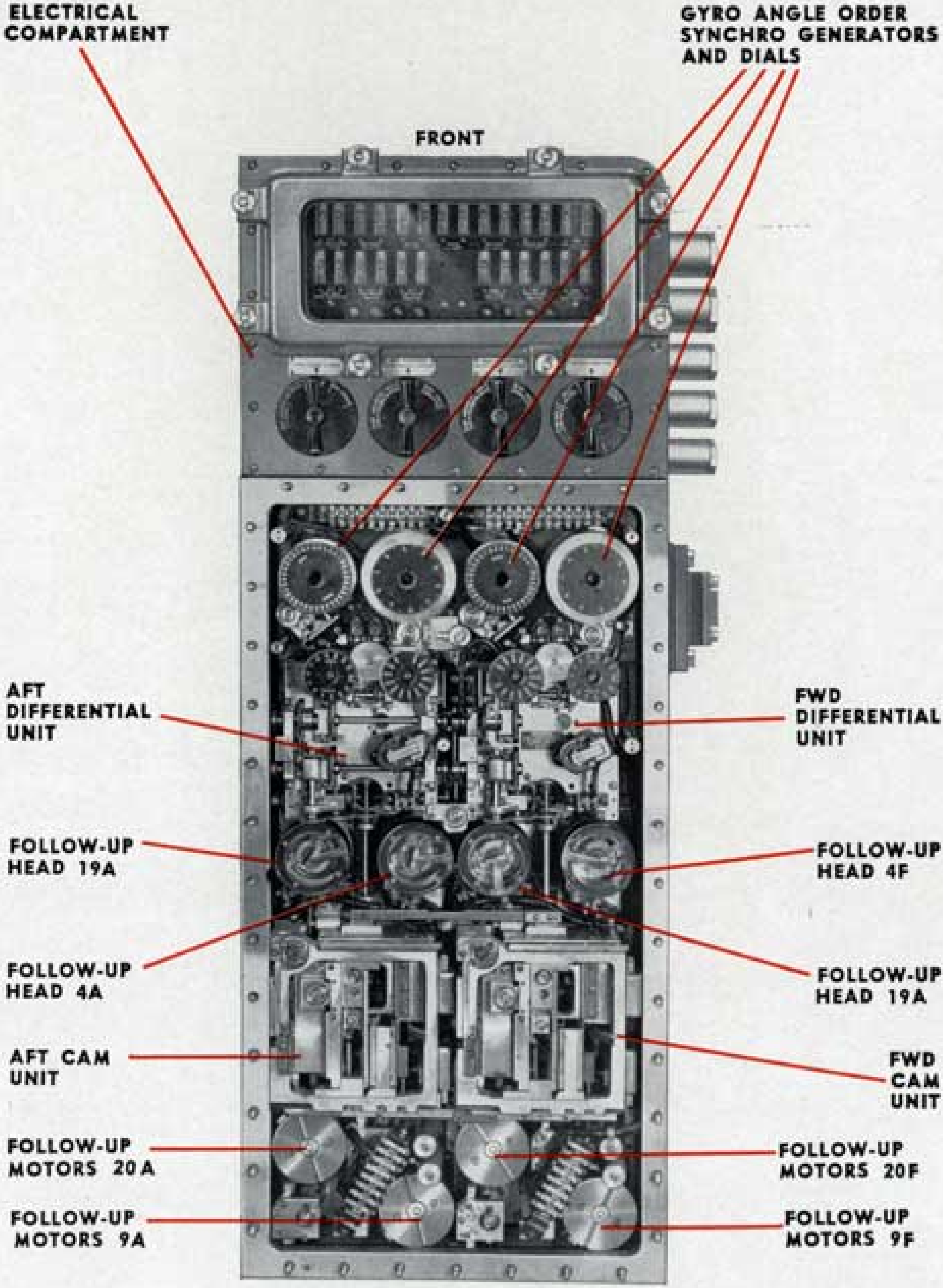


Fig. 100

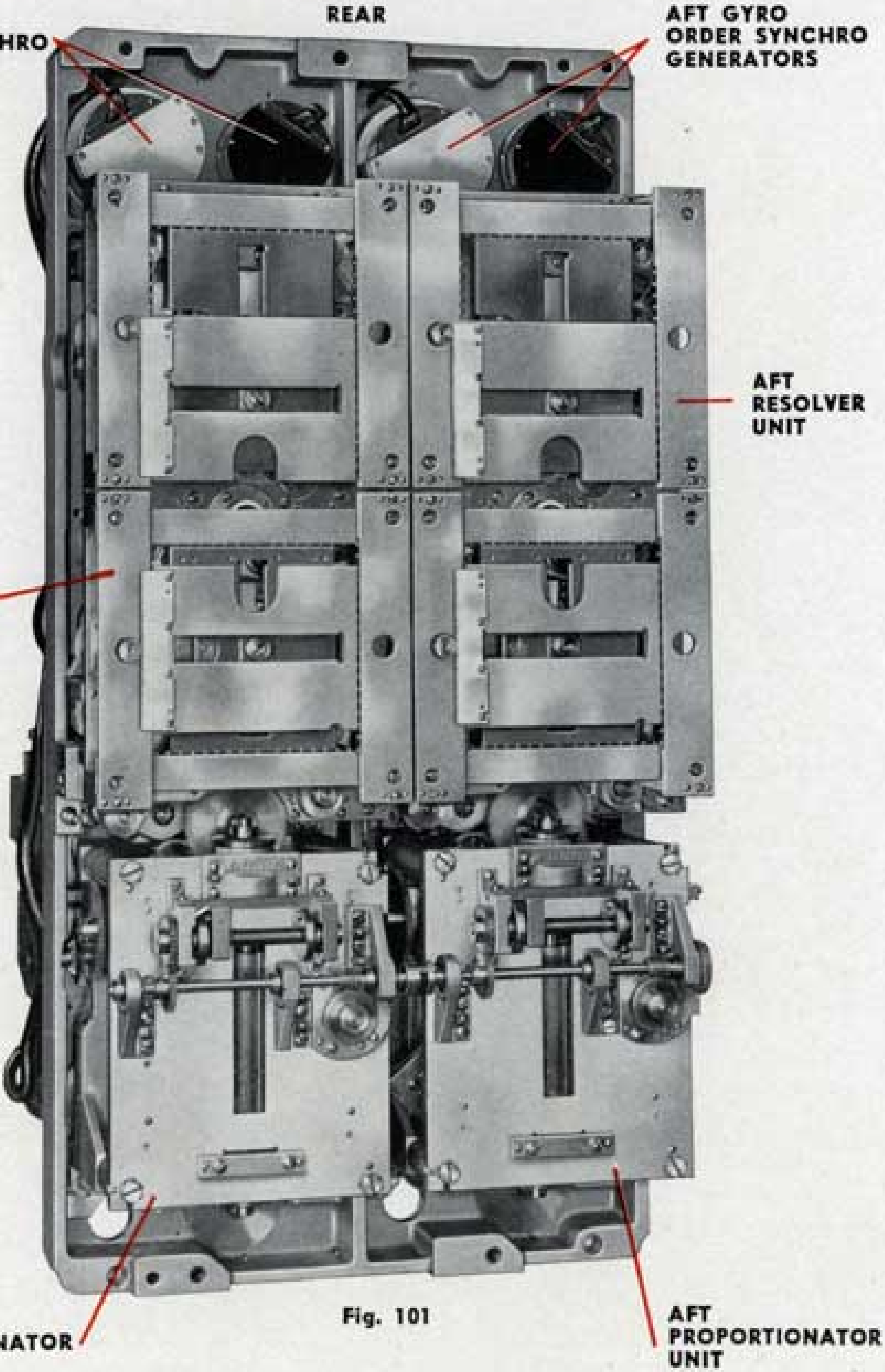


Fig. 101

All units of the Angle Solver mechanism are interconnected by means of shafting and gearing so as to conform to the gear diagram on Page 93A of this manual.

CONSTRUCTION

DIALS

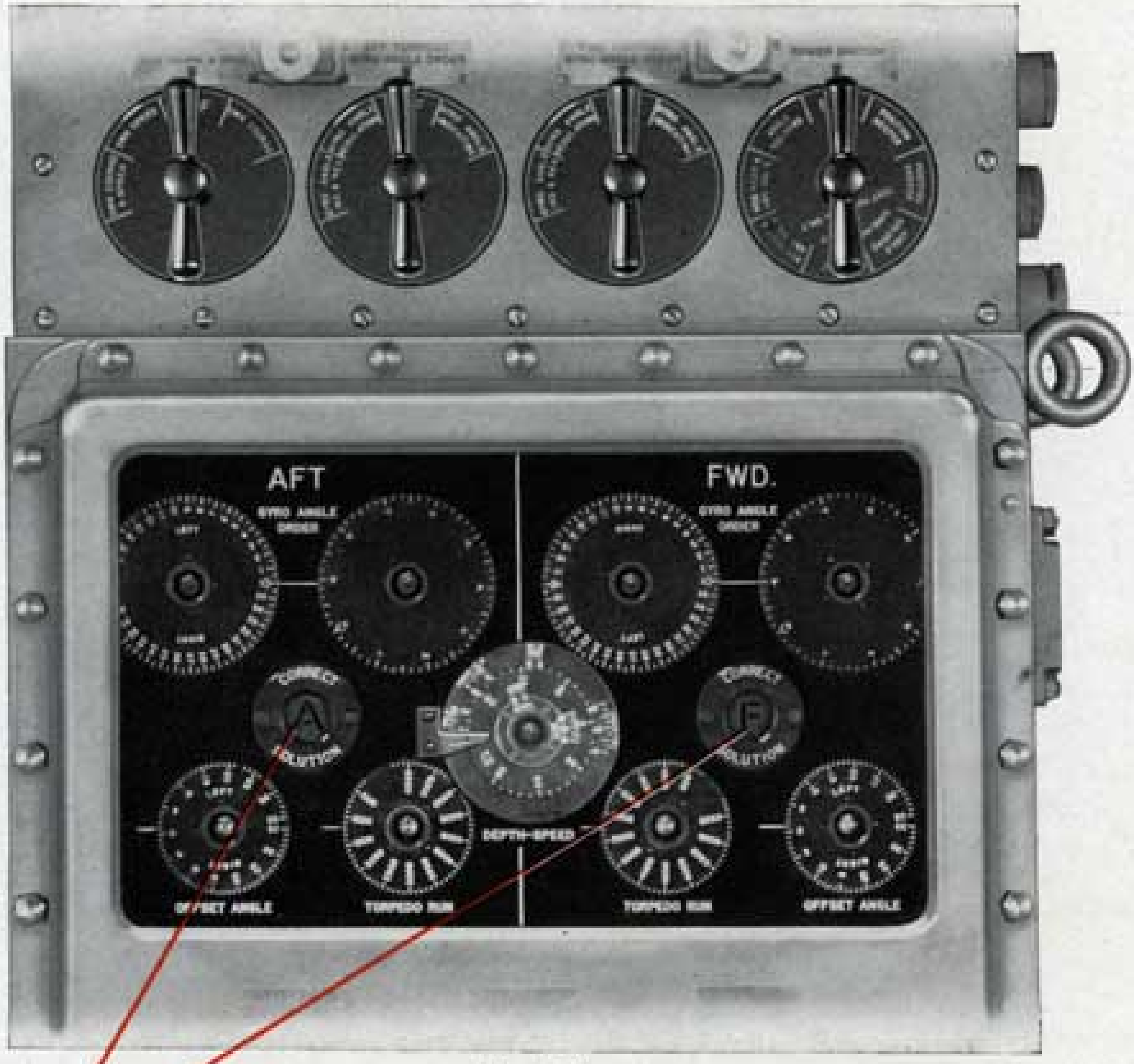


Fig. 102

CORRECT SOLUTION LIGHTS
(SEE NOTE)

Fig. 102 is a close-up of the dials of the Angle Solver Unit. As in the case of the Position Keeper, dial indications are read opposite engraved index lines in the index plate. The construction of these dials is similar in that they are engraved aluminum discs operating flush with the index plate and are secured to their mounting rings or shafts by means of small screws or by nuts which are removed or tightened by means of a synchro wrench. The only exception to this description is the Depth Set Dial, explained on Page 87.

NOTE: These lights glow when their respective Angle Solver is in synchronous operation.

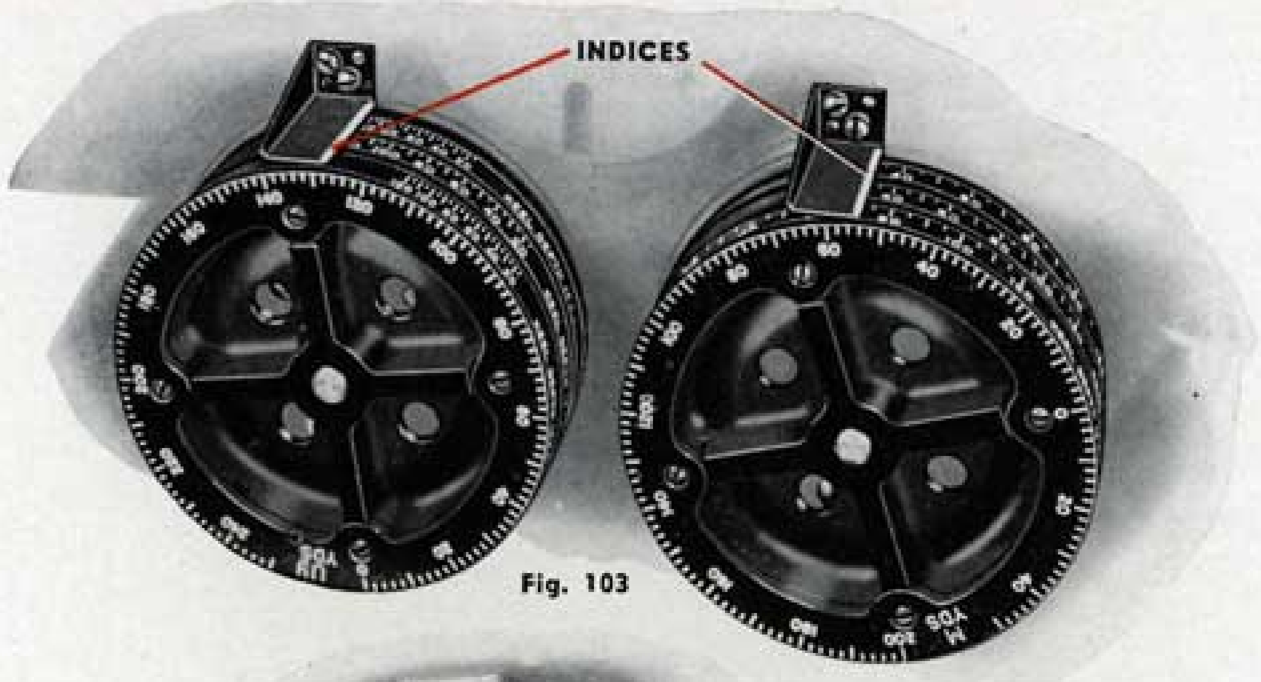


Fig. 103

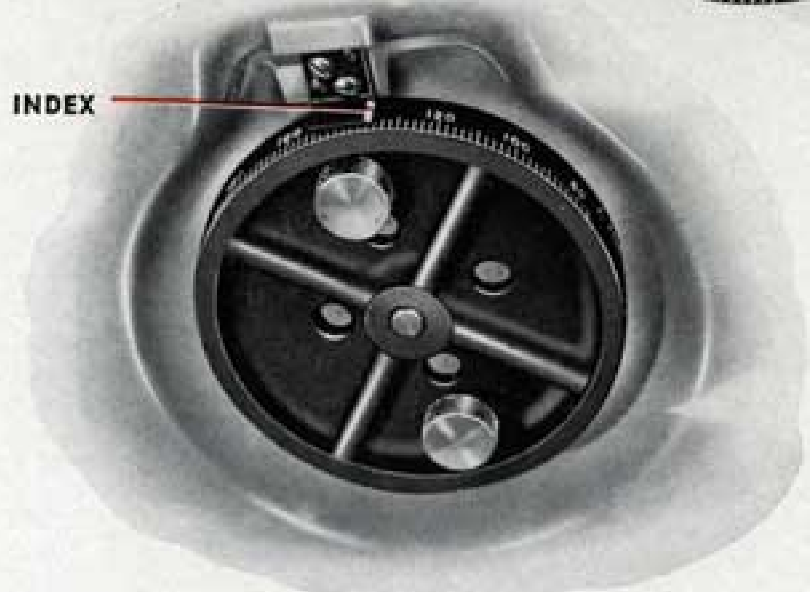


Fig. 104

Figs. 103 and 104 illustrate the input adjustments in which the input knobs are calibrated and are in themselves the indicators. These indicating knobs are of the drum type with calibrations engraved around the periphery of the drum as shown.

Fig. 103 shows the Torpedo Run Correction, Uy, Dials on the left and the Reach, M, adjustment on the right. The dials are "stacked" three deep and the index pointer for each set is a steel bar fastened to the chassis as shown in the figure. These dials are removable and can be changed according to the type of torpedo being used. Four screws hold the dials together when assembled.

The Turning Radius Knob is a single drum type dial as shown in Fig. 104. The dial is calibrated in yards and is read at the index pointer shown directly above the drum. This dial is normally kept covered by an access plate, as was seen in Fig. 99, Page 108.

CONSTRUCTION

INTERCONNECTION OF THE CASES

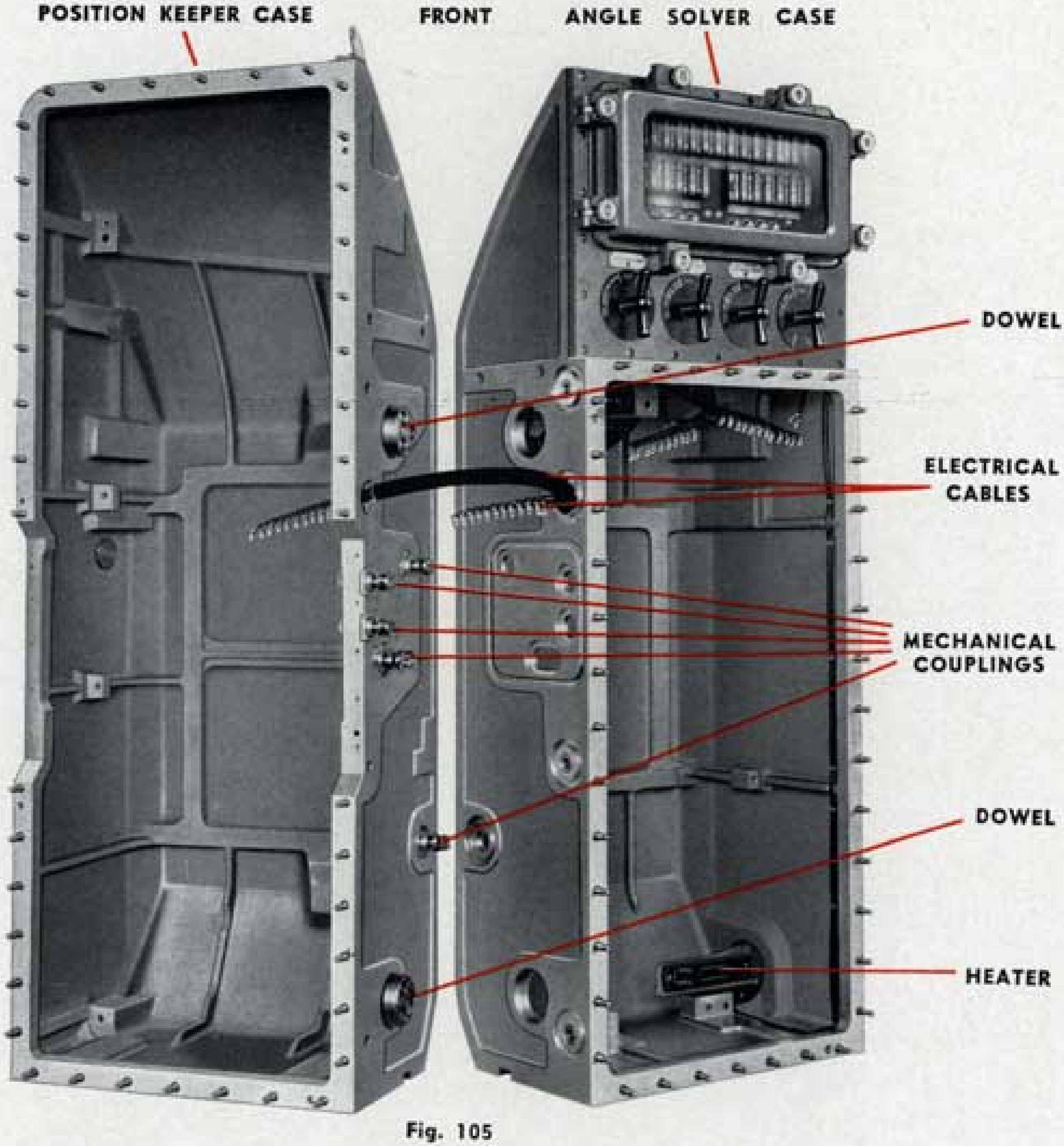


Fig. 105

By means of shafts and couplings, the Position Keeper is interconnected mechanically to the Angle Solver Unit. These shafts extend through adapters in the right side of the Position Keeper and through corresponding holes in the left side of the Angle Solver, as shown in Fig. 105. This figure also shows the case aligning dowels and the interconnecting electrical cables.

In the following pages the individual units are described in detail, particularly with reference to their construction.

RESOLVER UNIT

The fwd and aft Resolver Units are identical in construction, and the following description applies to either.

FRONT, TOP AND RIGHT

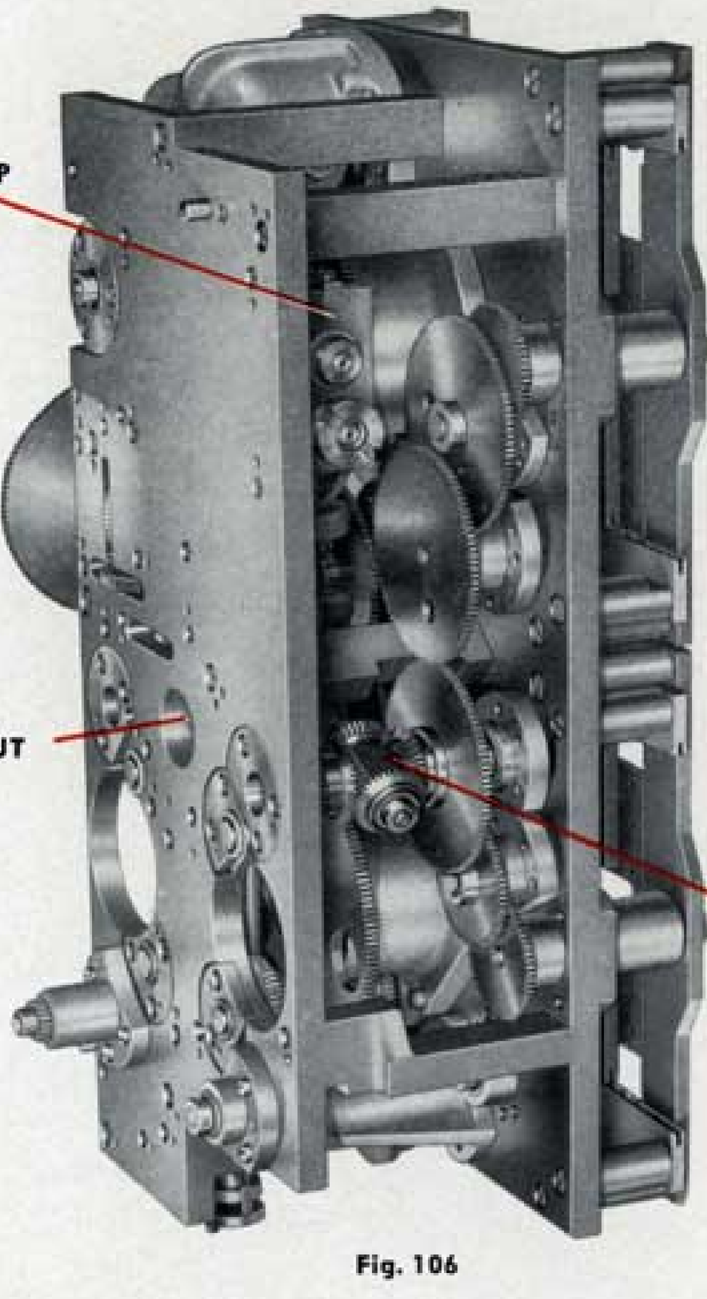


Fig. 106

Referring to Figs. 106 and 107, it can be seen that the Resolver Unit consists of two resolvers, one of which has as its two inputs the values of R and $G-Br$ and as its outputs $R\sin(G-Br)$ and $R\cos(G-Br)$. The other resolver has as its two inputs the values of H and I, and as its outputs $H\sin I$ and $H\cos I$.

One sine function is subtracted from the other sine function by the Differential 18FA, the difference R sin (G − Br) − H sin I being one output of the Resolver Unit. Similarly, one cosine function is subtracted from the other cosine function by the Differential 3FA, the difference R cos (G − Br) − H cos I being the other output of the Resolver Unit. These two outputs terminate in gears behind the front plate, one of which is shown in Fig. 107, these gears meshing with gears on the Angle Solver chassis when assembled. Three of the four input shafts and gears are also shown in Fig. 107. The location of the I input is indicated in Fig. 106.

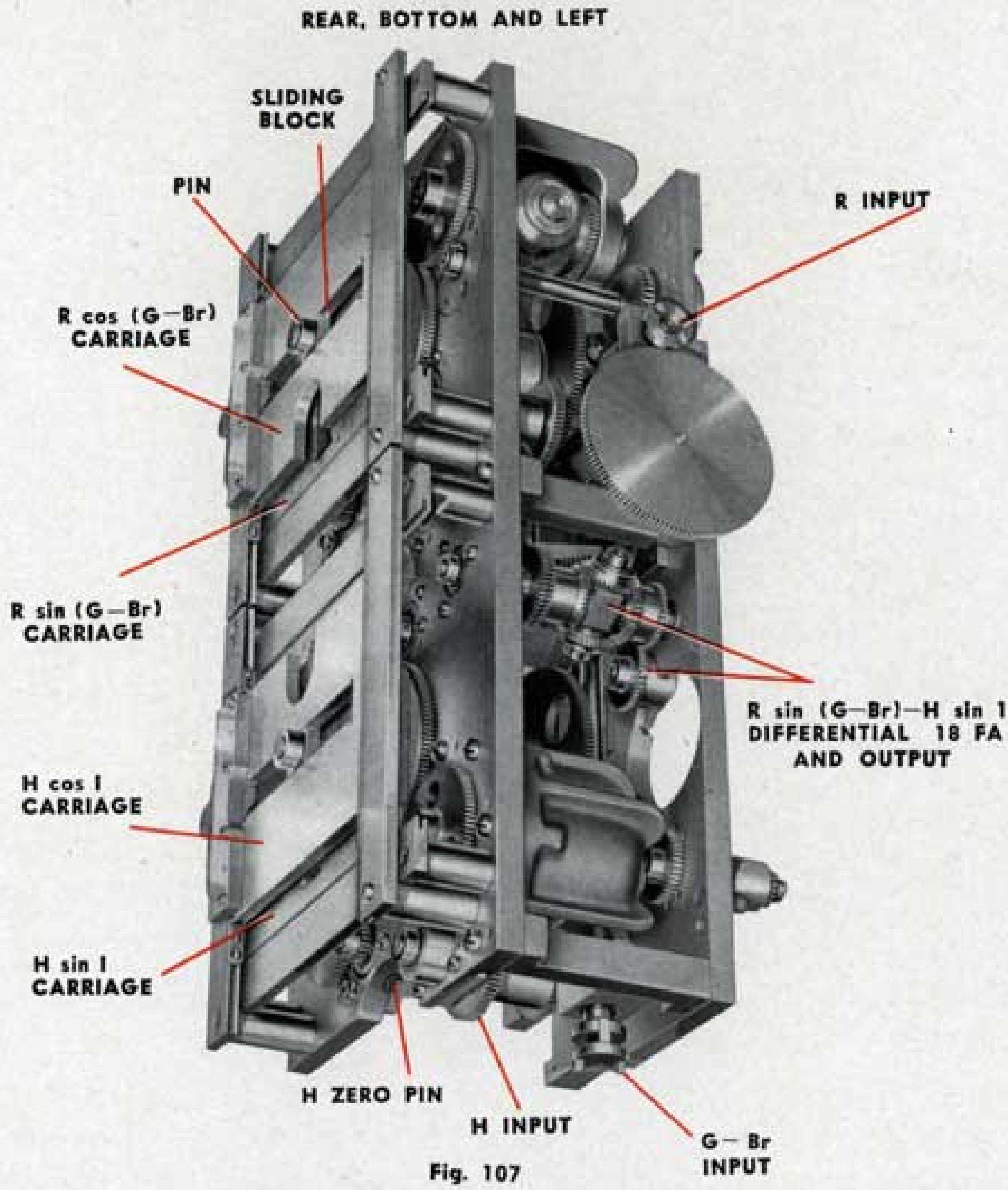


Fig. 107

The mechanism of the Resolver Unit is built on and between two rectangular aluminum plates approximately 9 x 18 inches in size and separated about 4 inches by spacers. Each resolver consists basically of a gear which represents an angle function, a sliding carriage on this gear which represents the hypotenuse of a triangle, two car-

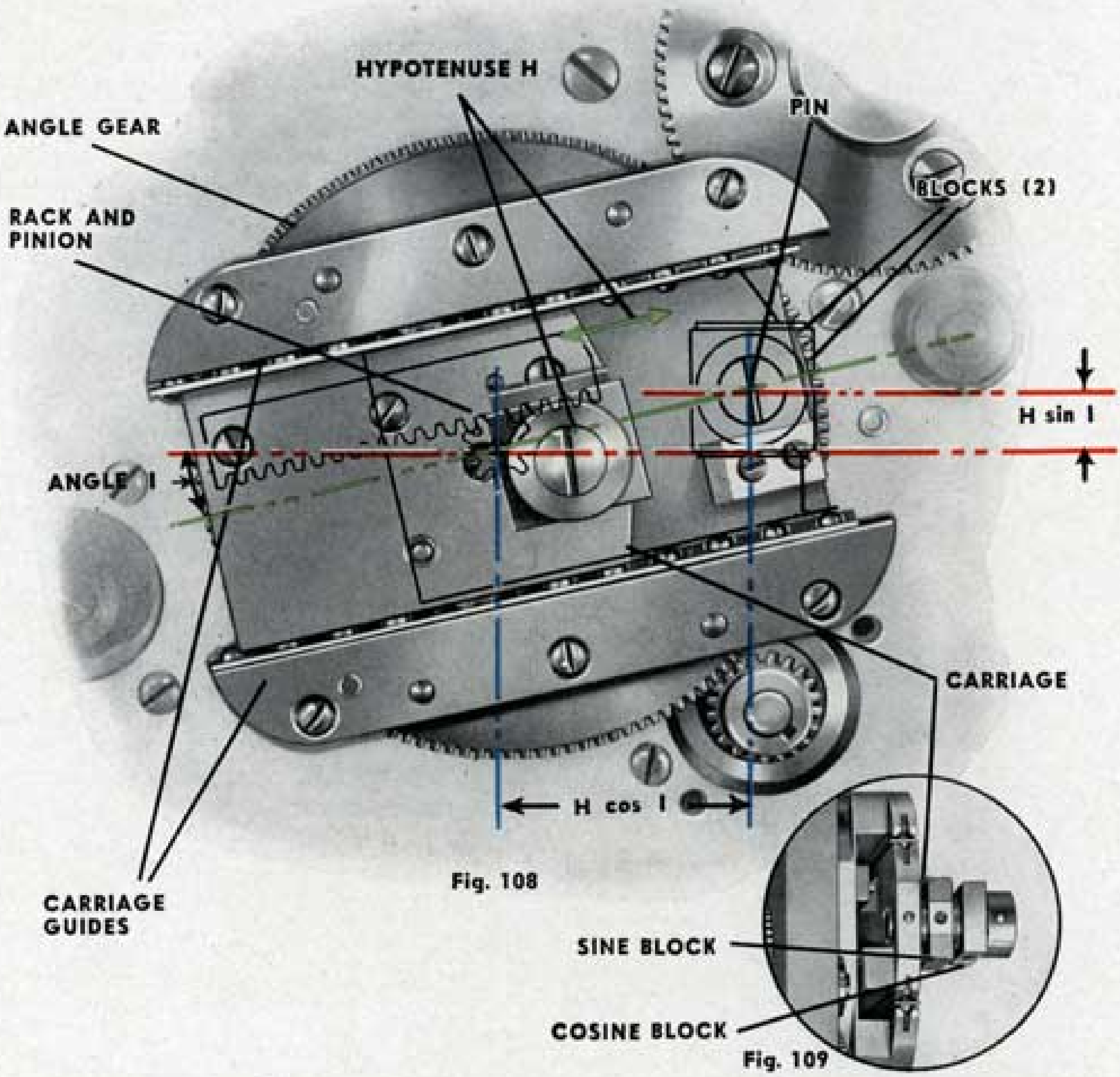


Fig. 108

Fig. 109

riages sliding at right angles to each other representing the product of the sine and cosine functions of the angle with the hypotenuse, and the necessary gears and differentials to interconnect these elements.

The angle gear is mounted on the face of the rear plate and carries in slides a small carriage which is positioned by means of a rack and pinion drive through the center of the angle gear. As seen in Fig. 108, the position of this carriage determines the length of the hypotenuse of a triangle, one angle of which is set in by the angle gear. A pin on this carriage acts as the pivot for two steel blocks, one behind the other. These two blocks are centered in slots in two large plates, Fig. 110A, the inner one being the

sine function carriage and the outer one the cosine function carriage. These carriages are mounted in straight ball bearings, Fig. 110B, in parallel planes, but

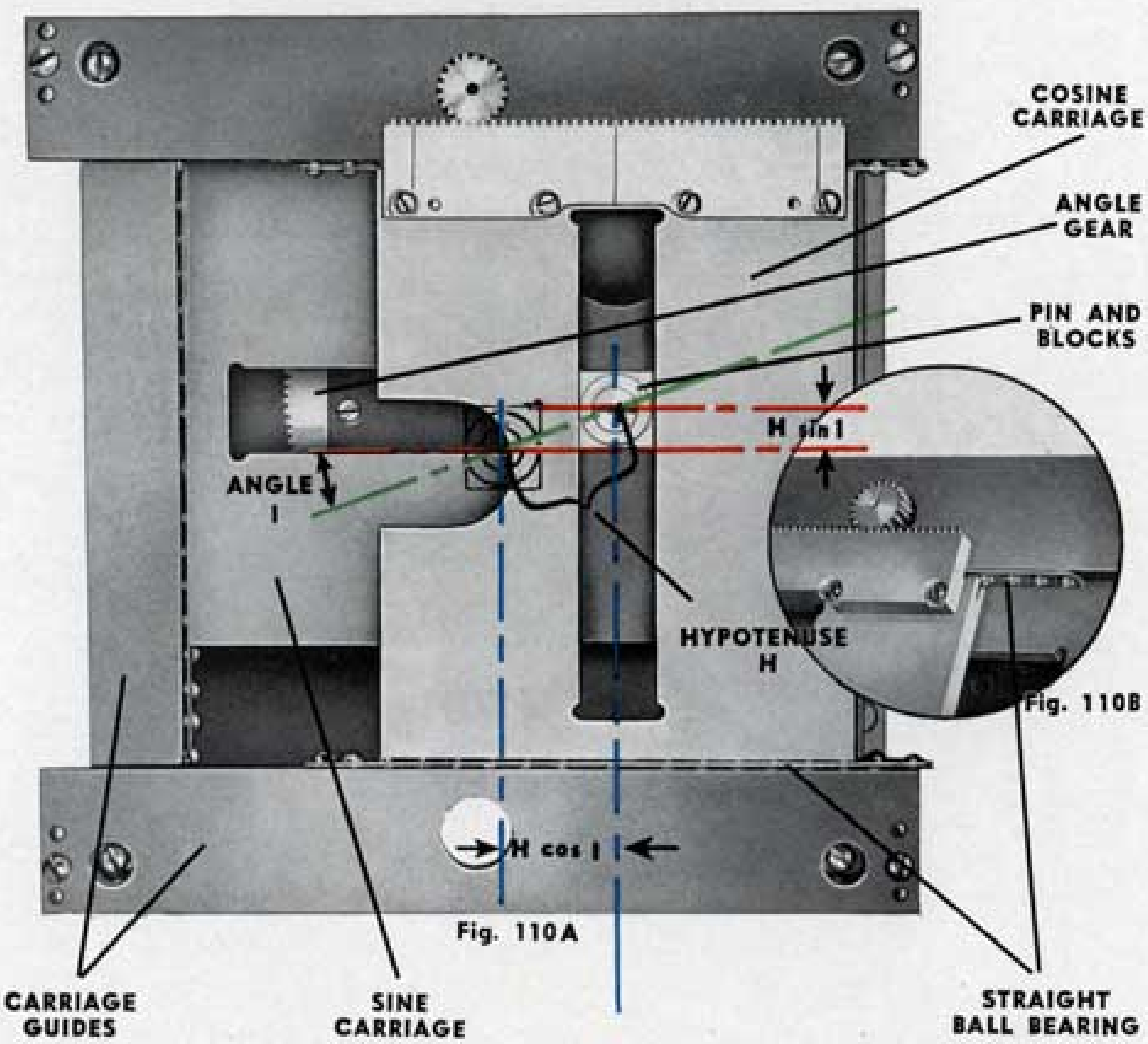


Fig. 110A

move at right angles to each other. The slot in each carriage is at right angles to the direction of carriage travel. The amount each large carriage moves depends upon both the angular motion introduced by the angle gear and upon the radius at which the pin operates, this radius being the hypotenuse input.

The position of the angle gear is determined by a train of gears located between the two mechanism plates, and the position of the small (hypotenuse) carriage is similarly determined. In order to compensate for the error that would enter the value of the hypotenuse input due to a change of angle, the angle gear train is connected to the

hypotenuse gear train by means of a mechanical differential, Q, Fig. 111A. This automatically cancels the error that would otherwise enter into the problem by turning the pinion of the rack-and-pinion drive through the same angle that is applied to the angle gear, thus preventing motion of the rack due to "rolling" about a stationary pinion. Fig. 111B shows how the hypotenuse rack would be re-positioned if the correcting

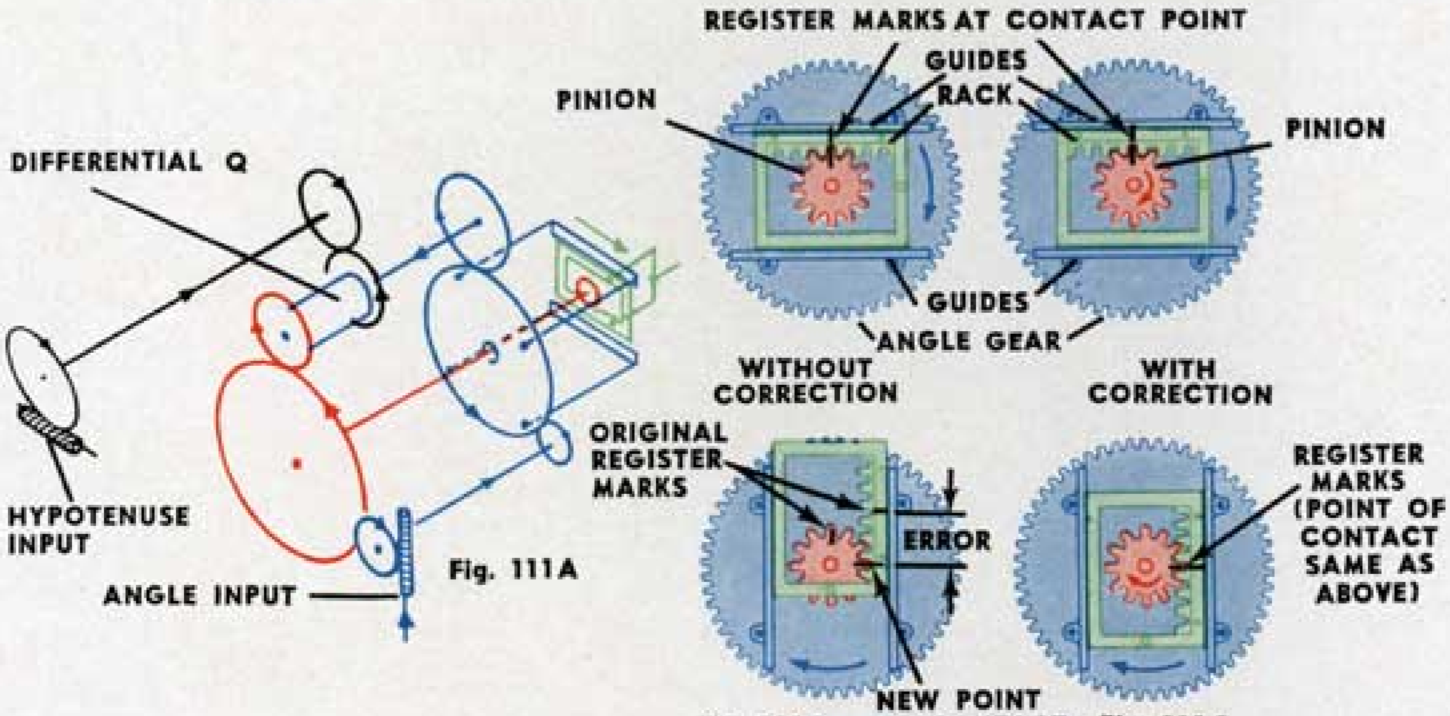


Fig. 111A

Fig. 111B

Fig. 111C

differential were not used. The upper sketch of diagram B shows the hypotenuse slide centered with respect to the hypotenuse input pinion. The point of contact between rack and pinion is indicated by black register marks. If the angle gear is now turned a part of a revolution in the direction indicated by the arrow, the rack "rolls" around the stationary pinion and assumes the position shown in the lower sketch of diagram B. New register marks at the point of contact show that the rack has been displaced by an amount indicated by the "error" dimension.

If the hypotenuse input pinion is caused to turn through the same angle as the angle gear, and simultaneously with it, as indicated by the arrows in the upper sketch of diagram C, the relationships will be as shown in the lower sketch of diagram C. In this case the register marks show that the point of contact between rack and pinion remains the same.

By introducing the differential in the gear trains as shown in diagram A, the small pinion is caused to rotate with the angle gear during an angle input, and no displacement of the hypotenuse carriage is permitted.

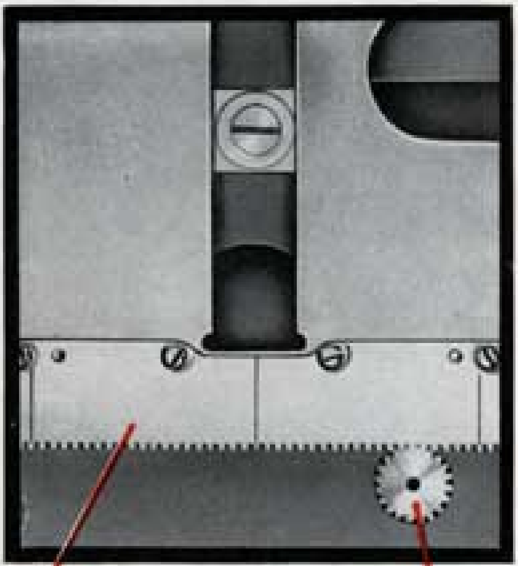


Fig. 112

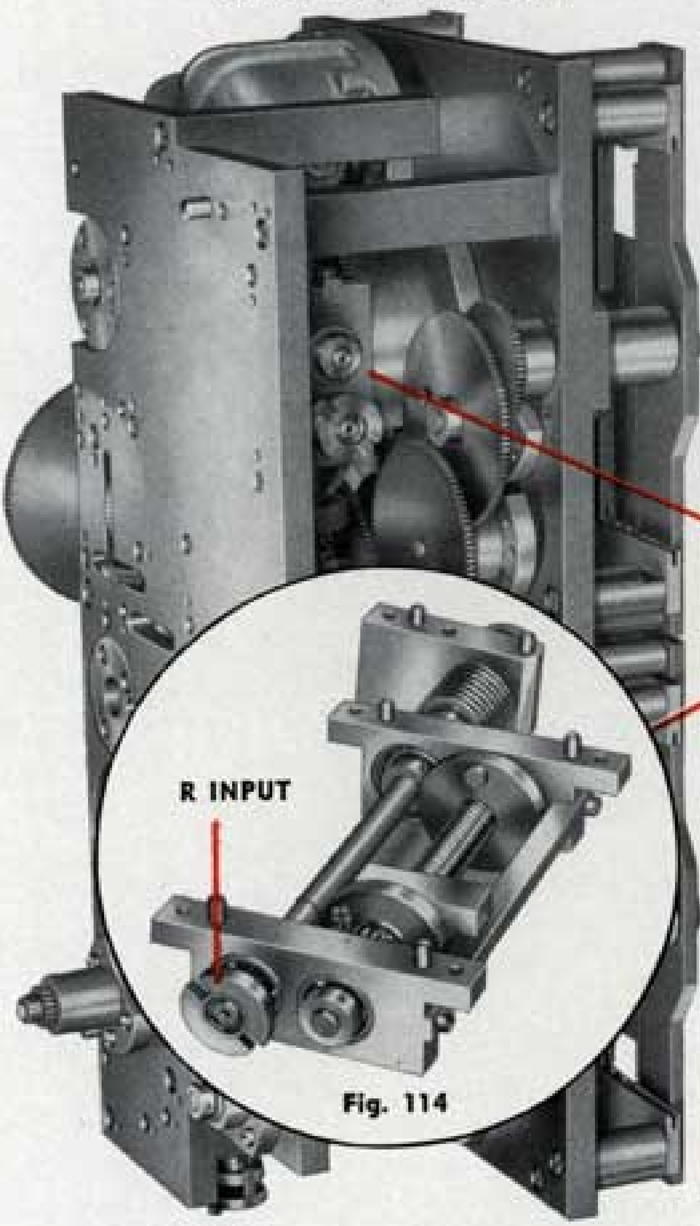


Fig. 114

Fig. 113

The outputs of the Resolver Unit are obtained as follows: Each of the large carriages carries a rack mounted parallel to its direction of travel, this rack meshing with a small spur gear, Fig. 112, which turns by an amount proportional to the product of the sine (or cosine) function and the hypotenuse. Thus, the outputs of the Resolver are taken off as rotary motions.

The front of the plate consists of a scraped surface equipped with two dowel pins for locating the Resolver Unit in its proper position on the Angle Solver chassis. It is secured by means of four hex head bolts and one screw which pass through the chassis and screw into the front plate of the unit.

The unit contains a Stop of the traveling nut type, see Fig. 114, for the R input gear train, located as shown in Fig. 113. There is also a zero pin in one of the spur gears in the H input gear train, by means of which the zero position of the H input may be readily determined. The location of this pin is shown in Fig. 107, Page 115.

PROPORTIONATOR UNIT

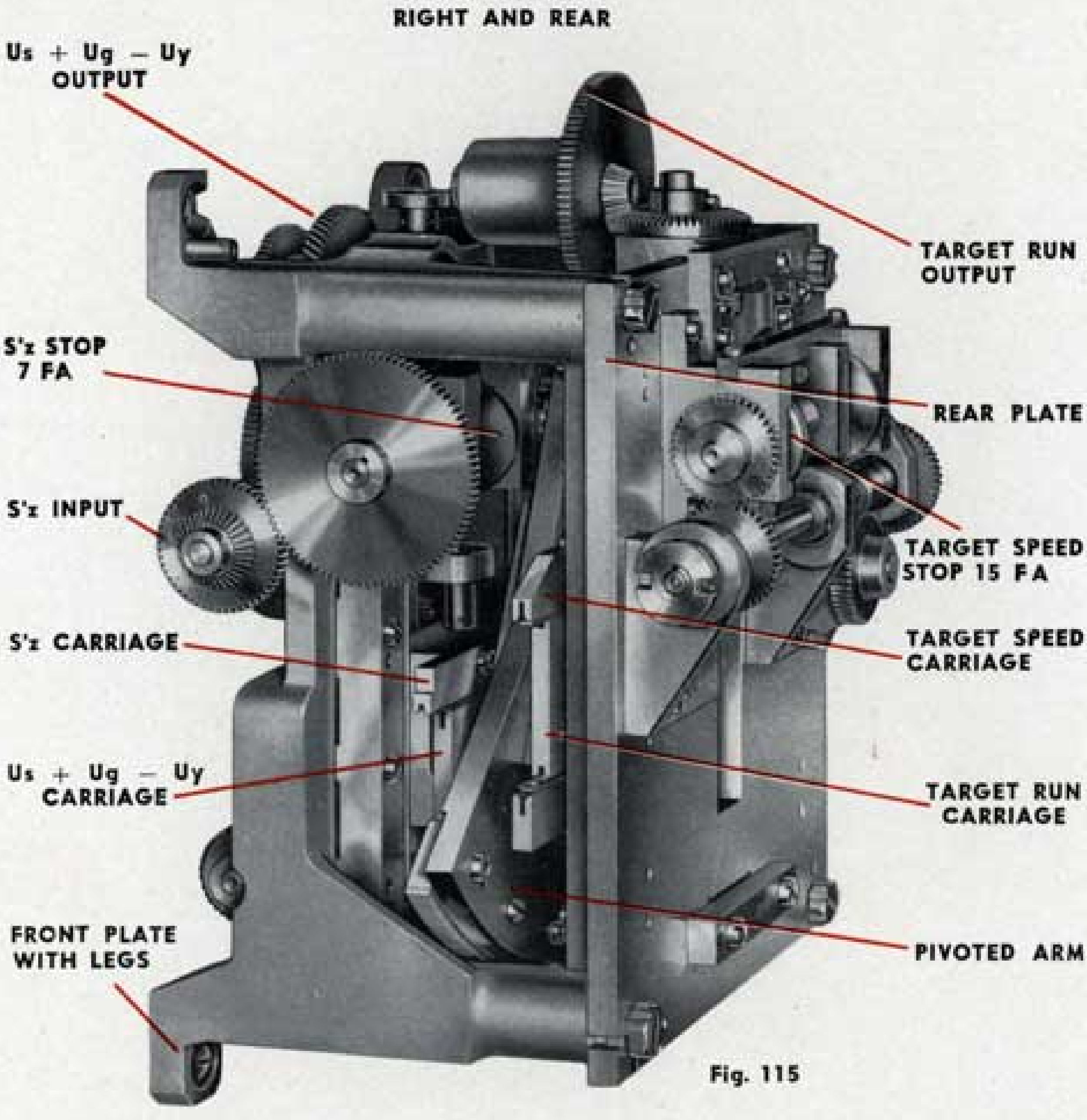


Fig. 115

The two Proportionator Units (one for fwd and the other for aft) in the Angle Solver section are identical in construction with the exception of a small bracket with its attached gearing which is secured to the left side of the aft unit. Also a worm which is right-handed on the aft unit is left-handed on the fwd unit. The following description applies to either.

The mechanism is mounted on and between two approximately square aluminum plates (8″ x 9″ in size) separated by about 4 inches.

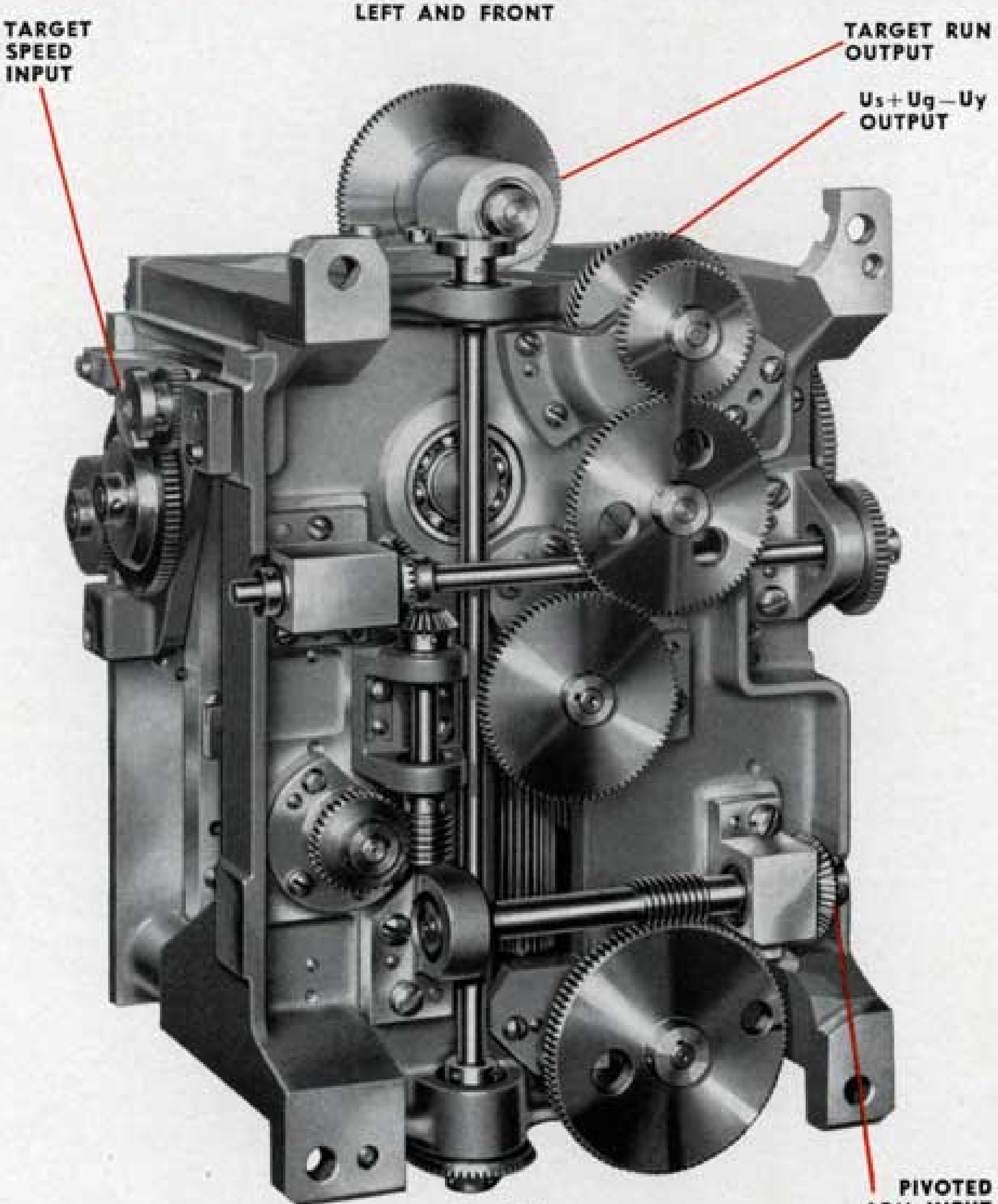


Fig. 116

Located between the two plates, see Fig. 115, is an arm which is pivoted at its upper end, the bearing support for which projects from the rear of the front plate. This arm is positioned by means of a sector gear and pinion drive.

The design of the instrument is such that $28\frac{1}{2}°$ tilt of the pivoted arm is equivalent to 230 seconds of Corrected Time of Torpedo Run. This is the maximum time for which the instrument can produce a correct solution.

$$T'a = K \tan X$$

where K is the design constant

$$230 = K \tan 28\tfrac{1}{2}^\circ$$

$$\tan 28\tfrac{1}{2}^\circ = .543$$

Hence K=424 approximately. Therefore the time represented by any other angle is

$$T'a = 424 \tan X$$

Secured to the front face of the rear plate are two vertically mounted parallel rails upon which travels a carriage which is positioned by the Target Speed gearing. Its travel is limited by a Stop, **15FA**, of the traveling nut type, refer to **Fig.** 117.

Upon the **Target Speed** carriage is mounted another carriage, representing **Target Run**, which moves in parallel rail guides at right angles to the **Target Speed** carriage rails. This carriage carries a pin and pivoted block which fits within the parallel rails on the pivoted arm.

As the **Target Speed** carriage is moved in a vertical direction, the **Target Run** carriage travels with it, its pin and block sliding within the parallel rails on the pivoted arm. If the parallel rails on the pivoted arm are vertical (parallel with the guide rails of the **Target Speed** carriage), there will be no horizontal motion of the **Target Run** carriage. However, if the pivoted arm and its rails are positioned at an angle with respect to the vertical, the **Target Run** carriage will move not only in a vertical direction, but also at right angles to the vertical. This horizontal motion is proportional to the angular displacement of the pivoted arm positioned by $\tan^{-1} Us + Ug - Uy/S'z$ from Follow-up Motor **9FA** and to the vertical displacement of the **Target Speed** carriage. It is "taken off" the carriage by means of a rack and a long pinion, along the length of which the rack slides as the carriages move vertically. This motion is **Target Run**.

Between the front plate and the front face of the pivoted arm is a set of rails and carriages similar to that shown in this figure, and which operates in a manner similar to that just described. The input to the vertically traveling carriage is the Corrected Torpedo Speed, S'z, for which there is a Stop, **7FA**, of the traveling nut type located as shown in **Fig.** 115, **Page** 120. The output motion of the **Torpedo Run** carriage rack and pinion drive is $Us + Ug - Uy$ and it has the same proportion with respect to S'z as H has to S at the same instant and for any given angular displacement of the pivoted arm.

On the front face of the pivoted arm there are also two parallel rails, the inclination of which will be the same as that of the pivoted arm which can vary from the vertical to approximately 28½° to one side of vertical.

The Proportionator Unit is secured to the rear of the Angle Solver chassis by means of four bolts and two locating dowels.

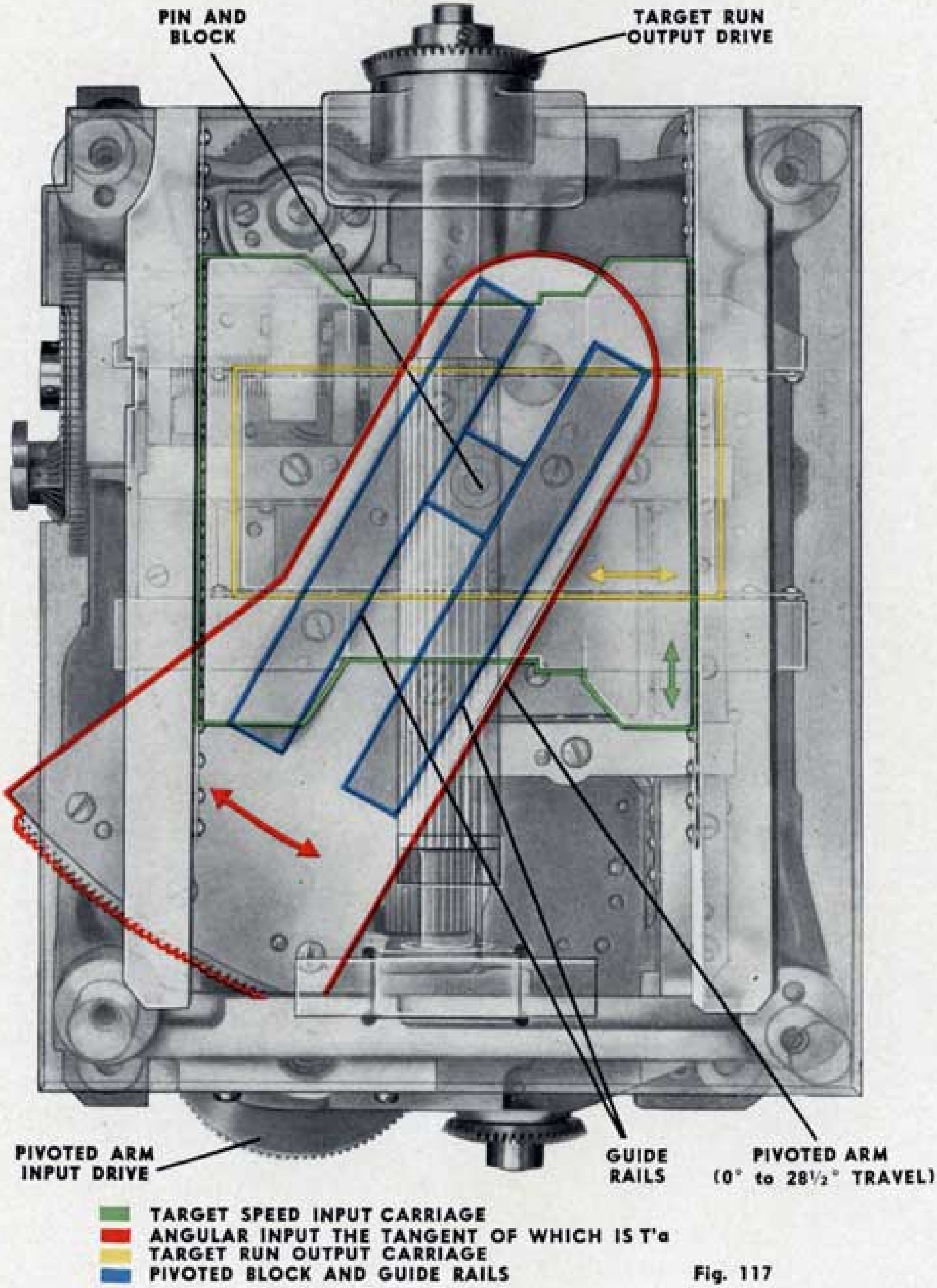

PIN AND BLOCK
TARGET RUN OUTPUT DRIVE
PIVOTED ARM INPUT DRIVE
GUIDE RAILS
PIVOTED ARM (0° to 28½° TRAVEL)
TARGET SPEED INPUT CARRIAGE
ANGULAR INPUT THE TANGENT OF WHICH IS T'a
TARGET RUN OUTPUT CARRIAGE
PIVOTED BLOCK AND GUIDE RAILS

Fig. 117

DIFFERENTIAL UNIT

The fwd and aft Differential Units are identical in construction with the following exceptions:

1. The A and Br input shafts on the front of the aft unit are longer than those on the fwd unit, extending to the right edge of the unit where couplings are mounted to connect with the left ends of the corresponding input shafts on the fwd unit.

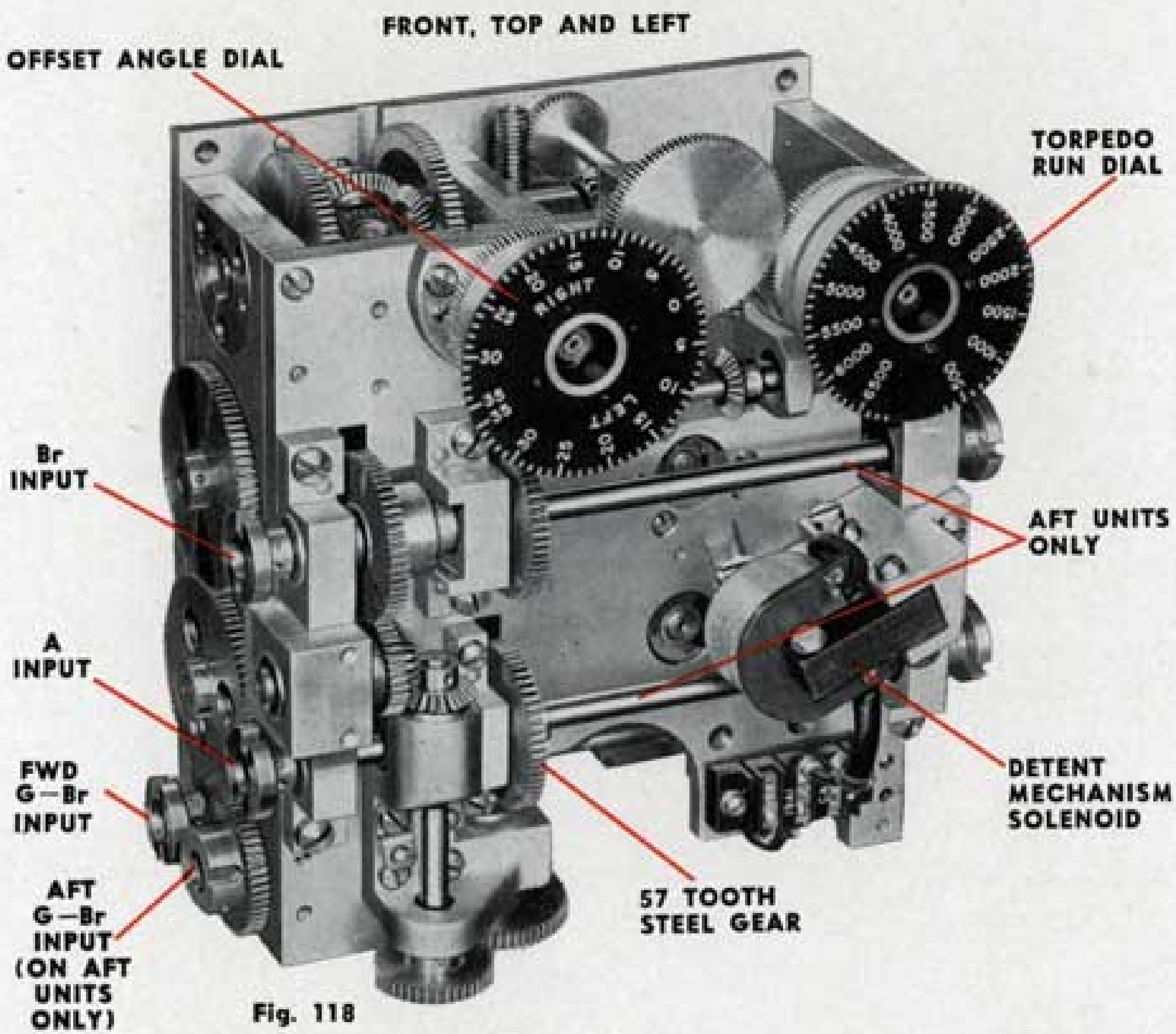


Fig. 118

2. In the lower front corner of the left side of the aft unit is a gear and coupling G—Br input which is not on the fwd unit; while on the fwd unit adjacent to the same location is a gear which is not on the aft unit. These differences are of a minor nature and do not prevent the interchanging of the aft and fwd units, provided the associated parts are also interchanged.

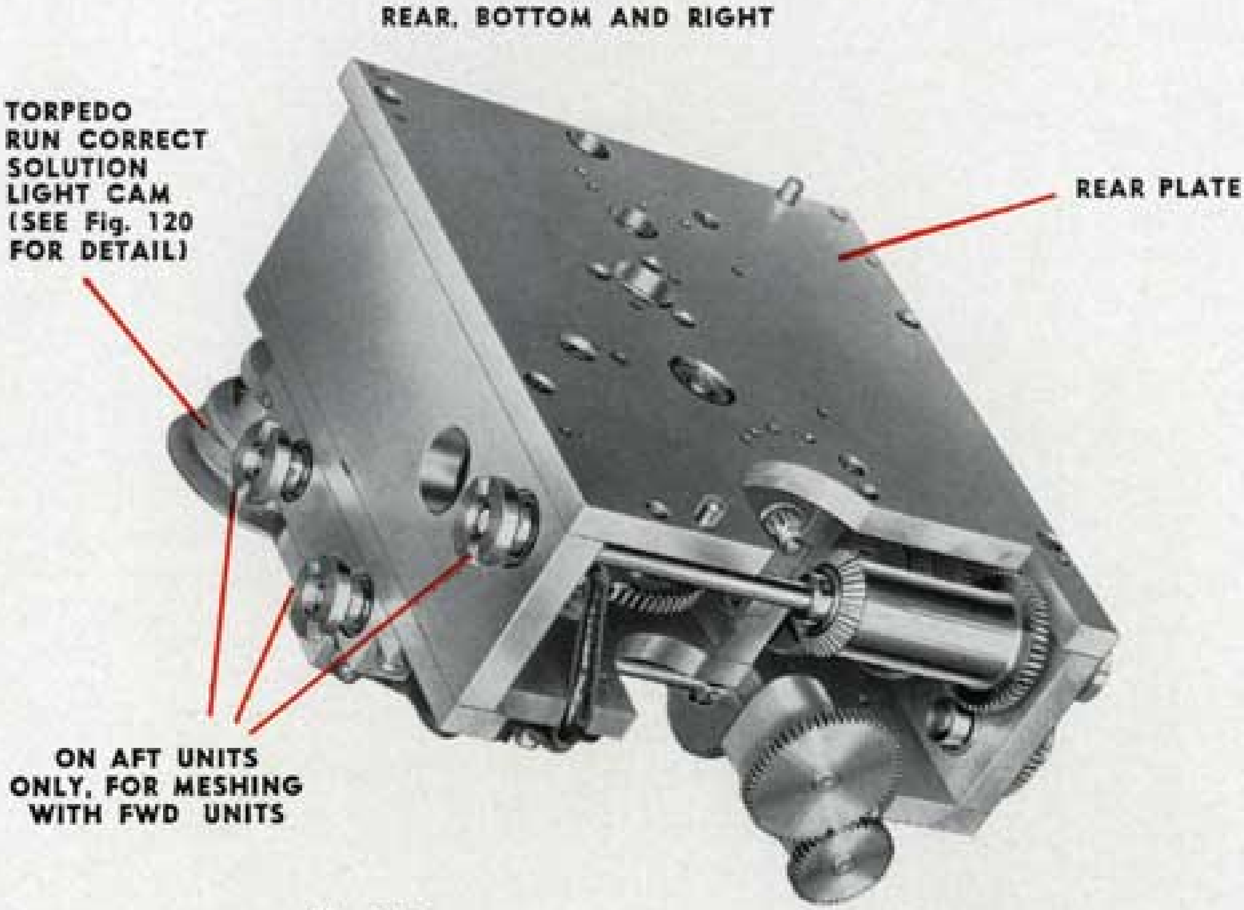


Fig. 119

The following general description applies to either fwd or aft Differential Unit:

Two aluminum plates approximately 8 inches square are separated about 3 inches by two rectangular spacers forming the side plates of the unit. Between the two main plates are located three mechanical Differentials (17FA, 22FA, and 23FA), a Stop, 28FA, of the traveling nut type in the Offset Angle Gear Train, and the interconnecting shafts and gears necessary to the function of the unit.

The two dials on the front plate, Fig. 118, indicate Offset Angle and Torpedo Run. Behind the Torpedo Run Dial is a cam which actuates a pair of contacts controlling the circuit of the correct-solution light of its respective Angle Solver. See Fig. 120.

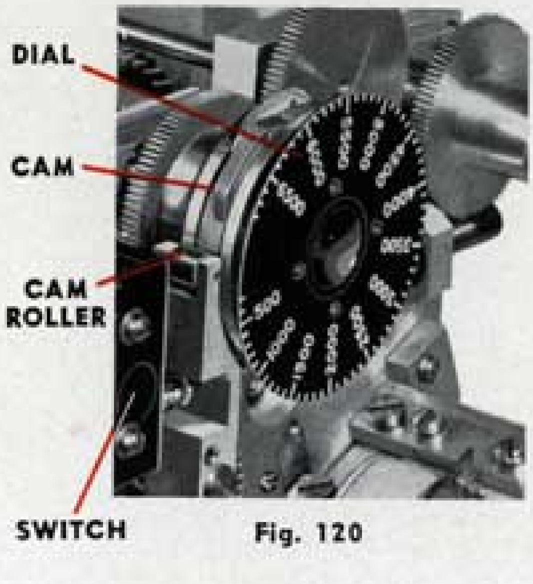


Fig. 120

DETENT MECHANISM

The Detent Mechanism shown in Figs. 121 and 122 consists of a solenoid operated plunger which contacts a detent in the driving gear of the Stop, 28FA, when de-energized.

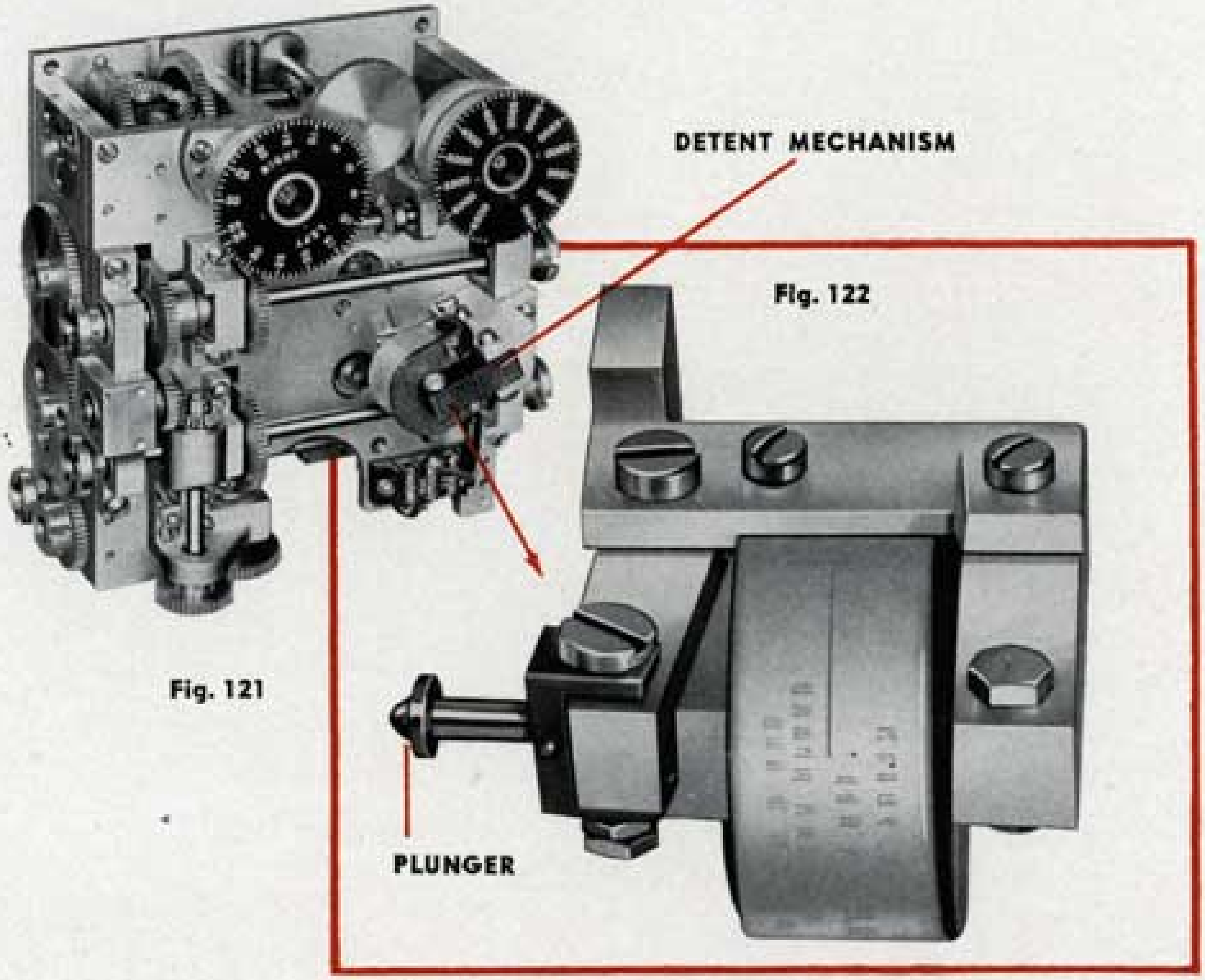


Fig. 121

Fig. 122

When the traveling nut of the Stop actuates the Switch, 38FA, the circuit to the solenoid is opened. De-energizing the solenoid allows the plunger to engage the detent in the drive gear. This locates the zero of Offset Angle. The gear containing the detent makes 1 revolution for 6 degrees of Offset Angle, and hence the detent will appear under the plunger at several values of Offset Angle. However, the traveling nut of the Stop will keep the solenoid energized (and the plunger retracted), at all values of Offset Angle except zero. The detent in the shaft is a shallow hole into which the plunger on

the solenoid fits. The pressure on the plunger is such that the shaft will be held against normal vibrations, but may be forced by turning the Offset Angle Handcrank. Fig. 122 is a close-up view of the solenoid and plunger.

DIVIDER UNIT

The Divider Unit is made up of three parts, an integrator, a follow-up head and a follow-up motor. The integrator consists of a rectangular aluminum plate about 4 x 8 inches in size upon which are mounted the elements shown in Fig. 123.

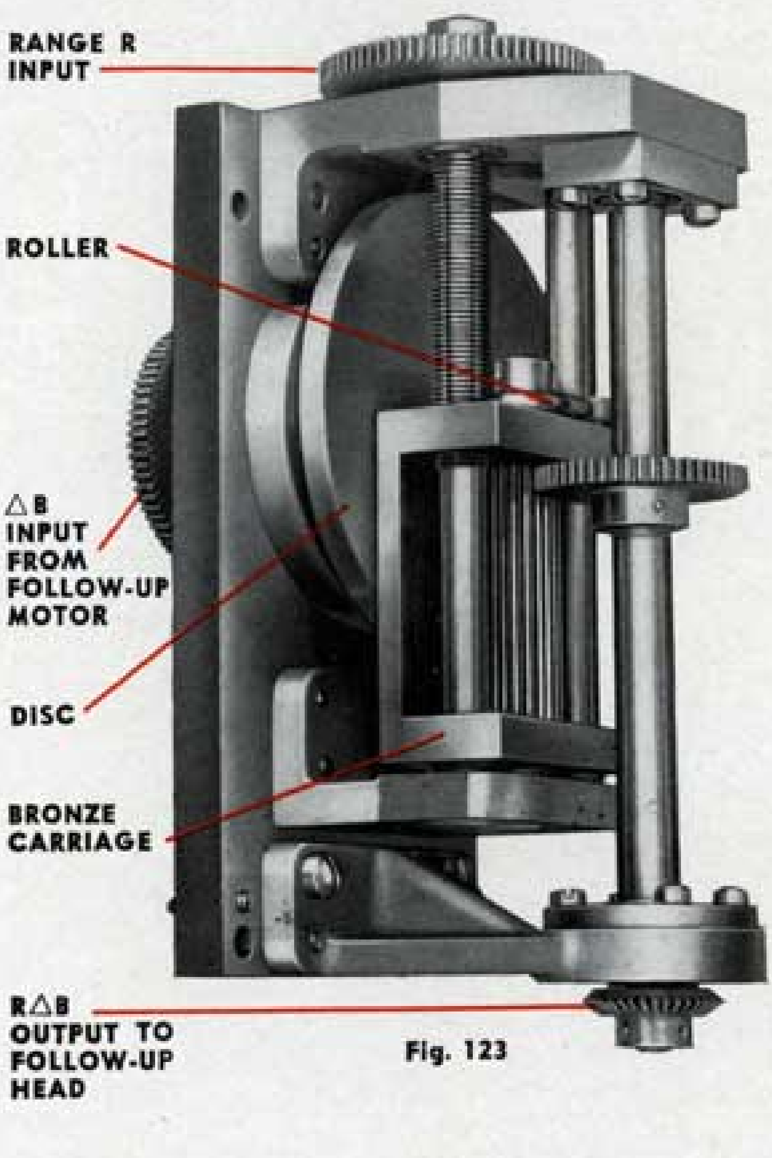


Fig. 123

Through the approximate center of the mounting plate projects a shaft, on one end of which is mounted the △B input gear (driven by the follow-up motor) and on the other end a hardened and ground steel disc 4 inches in diameter. In front of this disc a bronze carriage, free to move vertically, is mounted on round guides supported by brackets, as shown in the figure. One of these guides is threaded for about half its length and engages a threaded hole in one end of the carriage; thus, by turning the threaded guide rod (by means of the Range input) the carriage is positioned at any point within its limit of travel.

The carriage supports a long spur gear which is driven by a hardened and ground steel roller which in turn is driven by the large disc. The disc is spring-loaded so as to bear against the roller with a force of 10 to 16 pounds. As the disc rotates it turns the roller. The turning of the roller is transmitted by the long spur gear to a spur gear which drives the output shaft to the follow-up head.

TIME MOTOR GOVERNOR

This unit is shown in Figs. 124 and 125. The cast aluminum mounting bracket which supports the governor assembly is secured to the Position Keeper chassis so that the bevel gear engages a similar bevel gear on the output mechanism of the Time Motor. The bevel gear drives the rotating disc upon which are mounted two ball-bearing pivoted arms, each of which carries a contact and an adjustable weight as shown in the figure. Collector rings and brushes serve to connect the contacts to the external circuit.

Four coil springs act to hold the contacts together against the centrifugal

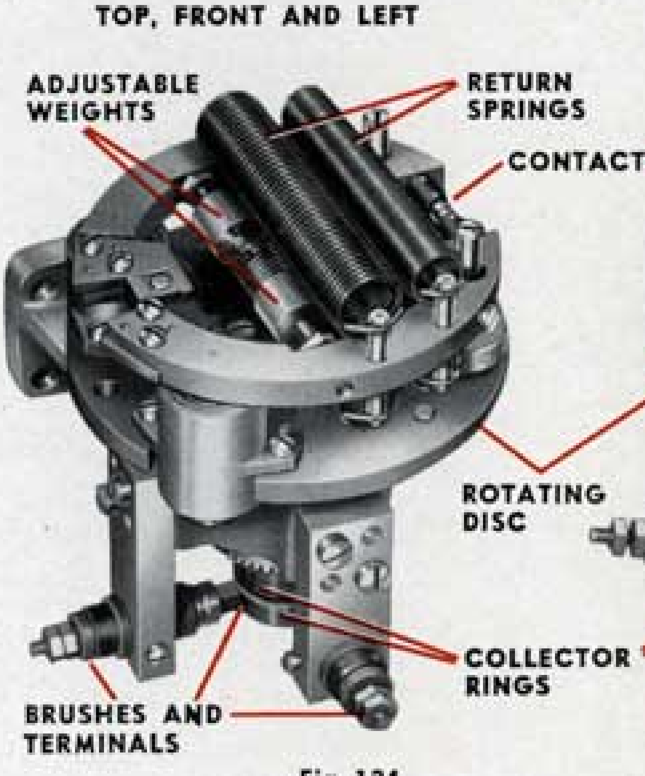


Fig. 124

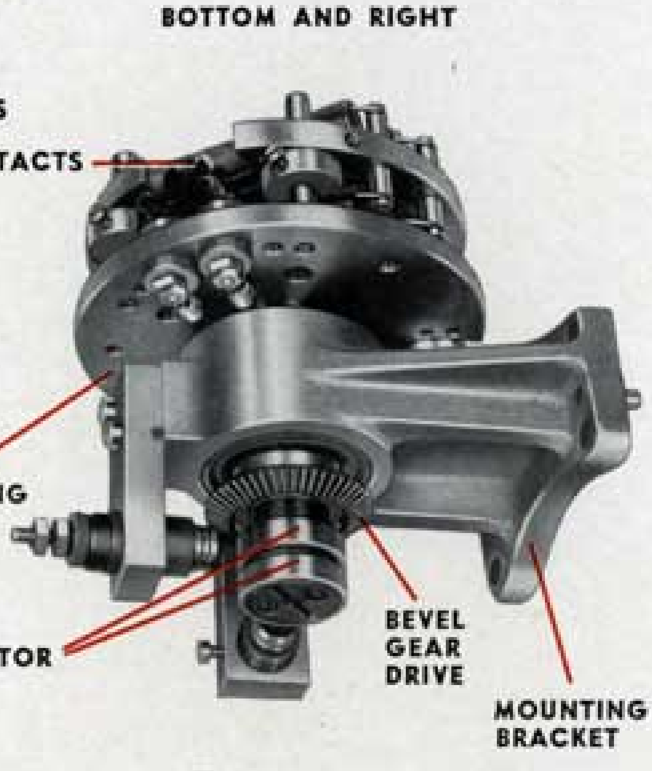


Fig. 125

force of the arms and weights, equilibrium being attained at 1200 R.P.M. At this speed the contacts separate and cause the Time Motor to slow down. This reduction in speed causes the centrifugal force to diminish and allows the springs to close the contacts again. This action continues several times per second and holds the motor to an average of 1200 R.P.M. The fundamental circuit for this type of control is shown in Fig. 126.

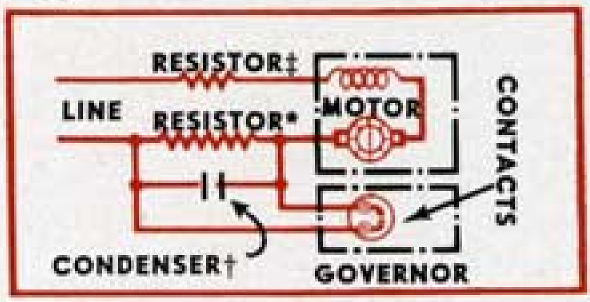


Fig. 126

‡Resistor is of such value that with governor contacts closed, motor will run at just slightly over 1200 R.P.M. with full load.

*Resistor is of such value that with governor contacts open, motor will run at just slightly under 1200 R.P.M.

†Condenser to reduce arcing across governor contacts.

INTEGRATOR UNIT

The Integrator Unit consists of a rectangular aluminum plate about 18 x 18 inches in size to which are secured six disc and roller assemblies.

Fig. 127 is a rear view of the unit showing at the right side two of the integrator assemblies, the upper one being the Target Speed assembly, and the lower one the Own Speed assembly.

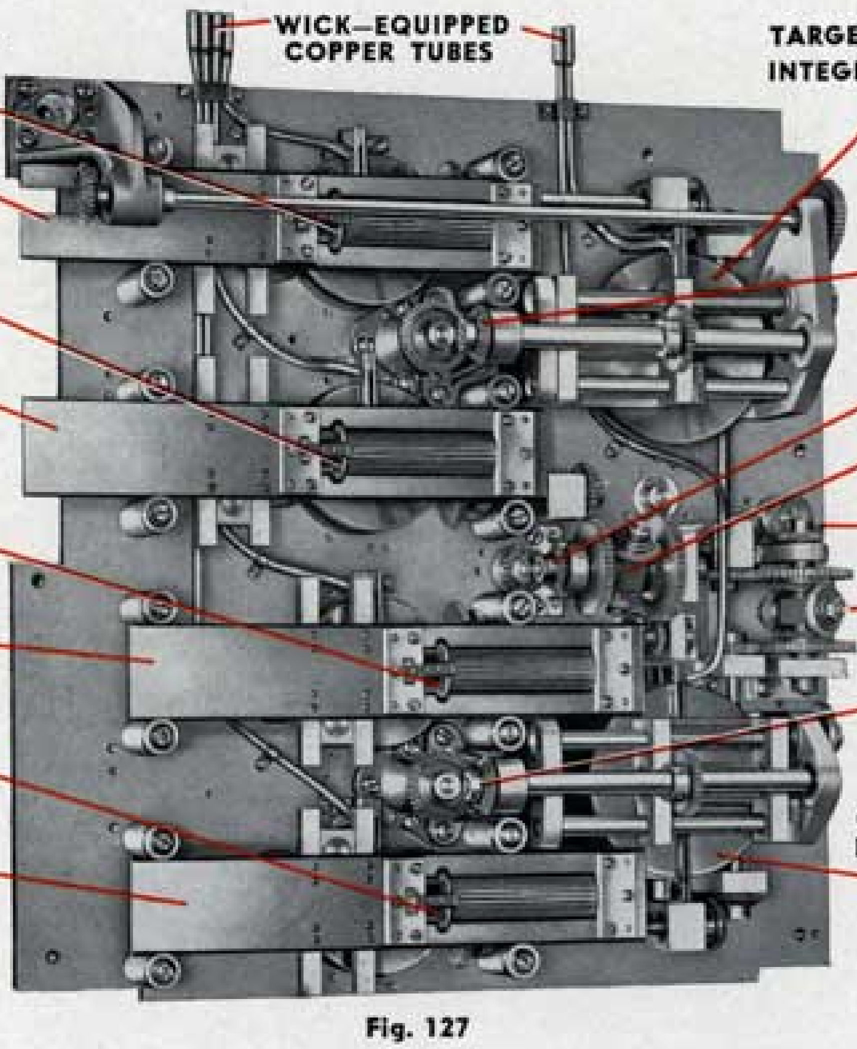


Fig. 127

The two discs for these assemblies are geared together and are both driven by the Time Motor at a speed of 187½ R.P.M., the driving and connecting gearing being located on the front of the mounting plate as shown in Fig. 128, Page 130.

The adjustable roller driven by the Target Speed integrator disc is positioned by the Target Speed input gearing, shown in Fig. 128. The adjustable roller driven by the Own Speed integrator disc is positioned by the Own Speed input gearing, likewise shown in Fig. 128.

The Target Speed carriage roller, whose output is $\int$SdT, drives the two integrator discs shown at the upper left of the unit in Fig. 127, Page 129. The interconnecting gearing for the discs is shown at the upper right of Fig. 128.

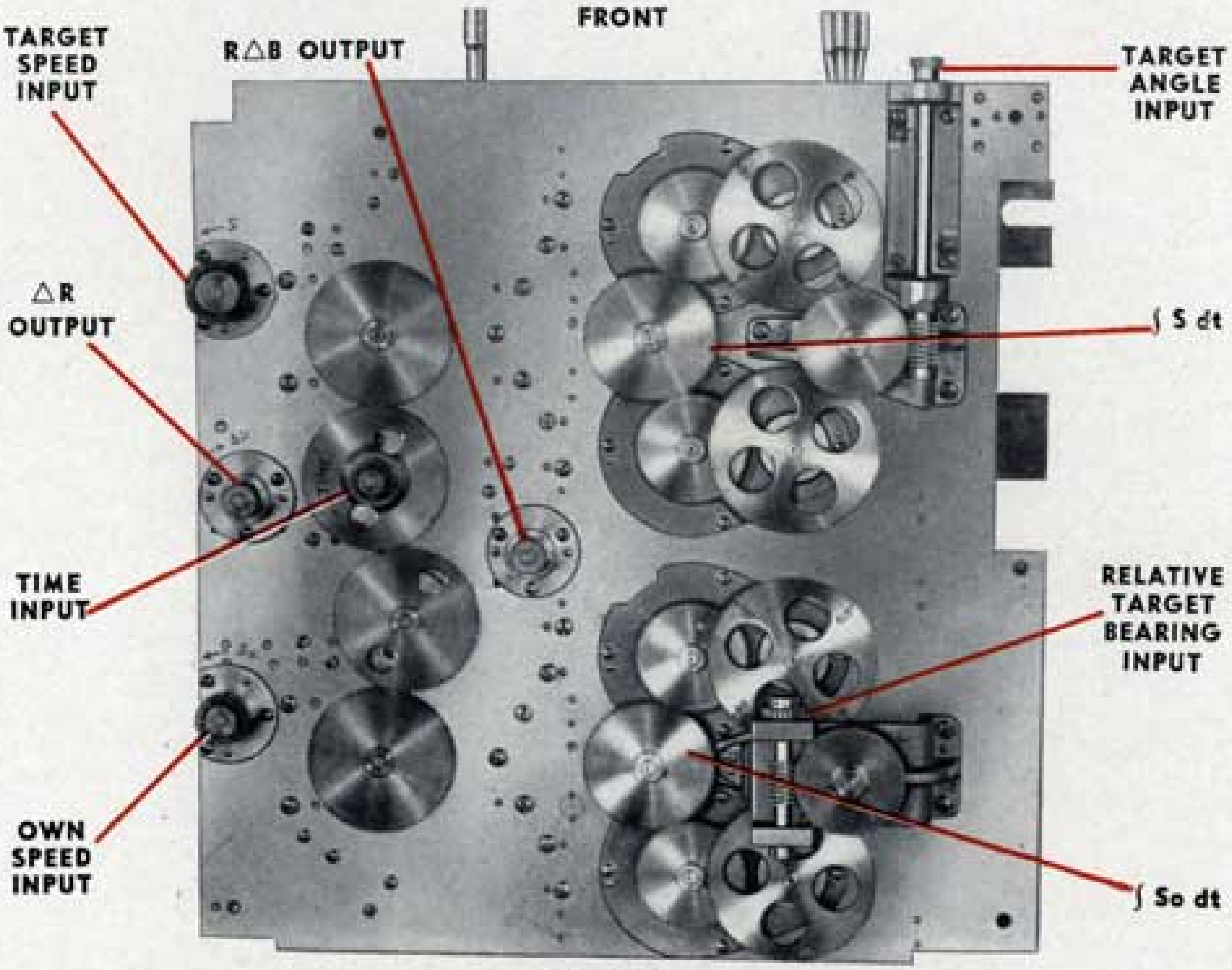


Fig. 128

Likewise, the Own Speed carriage roller, whose output is $\int$SodT, drives the two integrator discs shown at the lower left of the unit in Fig. 127, Page 129. The interconnecting gearing for these discs is shown at the lower right of Fig. 128.

The remaining gearing at the top right of Fig. 128, driven by the Target Angle input, serves to position properly the sin A carriage and cos A carriage rollers on their respective discs. The remaining gearing at the bottom of Fig. 128, driven by the Relative Target Bearing input, serves to position the cos Br carriage and sin Br carriage rollers on their respective discs.

This positioning is accomplished by means of pin and block mechanisms offset on the input shafts, each block sliding in vertically mounted guide rails secured to the corresponding carriage, and resolving the angle into its sine or cosine function. The design is such that the hypotenuses of these resolvers are each equal to unity. Fig. 129 shows the sin A carriage with its connecting mechanism.

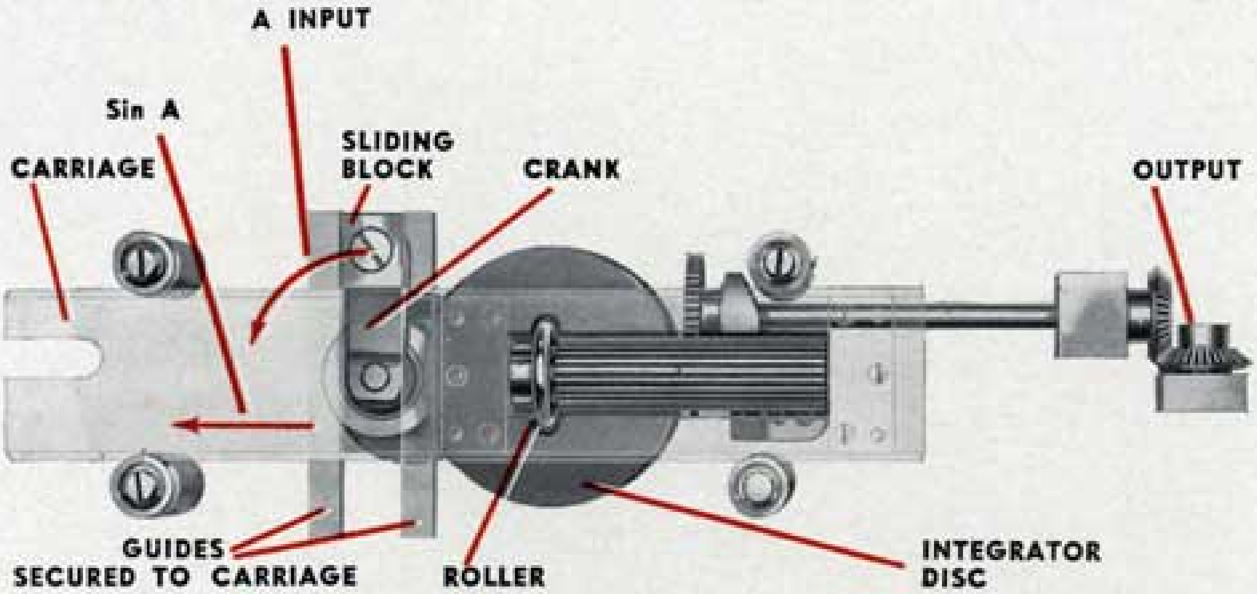


Fig. 129

The motions of the $\int S \sin A dT$ roller and the $\int So \sin Br dT$ roller are added together by the Differential 28, Fig. 127, Page 129, the combined output being equivalent to $\int S \sin A dT + \int So \sin Br dT$. This sum equals $R \triangle B$, and a shaft for this output projects through to the front of the plate and is driven by bevel gears from the output of the differential.

Likewise, the motions of the $\int S \cos A dT$ roller and $\int So \cos Br dT$ roller are combined in Differential 29, Fig. 127, Page 129, the combined output in this case being equivalent to $\int S \cos A dT + \int So \cos Br dT$. This sum equals $\triangle R$, and a shaft for this output projects through to the front of the plate, being likewise driven by bevel gears from the differential output.

Each integrator disc is equipped with an oiled felt wiper, lubrication being supplied through wick-equipped copper tubes. The entire unit is secured to the rear of the Position Keeper chassis by six screws.

SOUND BEARING CONVERTER

The Sound Bearing Converter consists of three interconnecting units mounted on a rectangular aluminum plate approximately 12 x 18 inches in size.

Referring to the rear view of the Converter, Fig. 130, the unit at the upper right is a small resolver, a cutaway view of which is shown in Fig. 131.

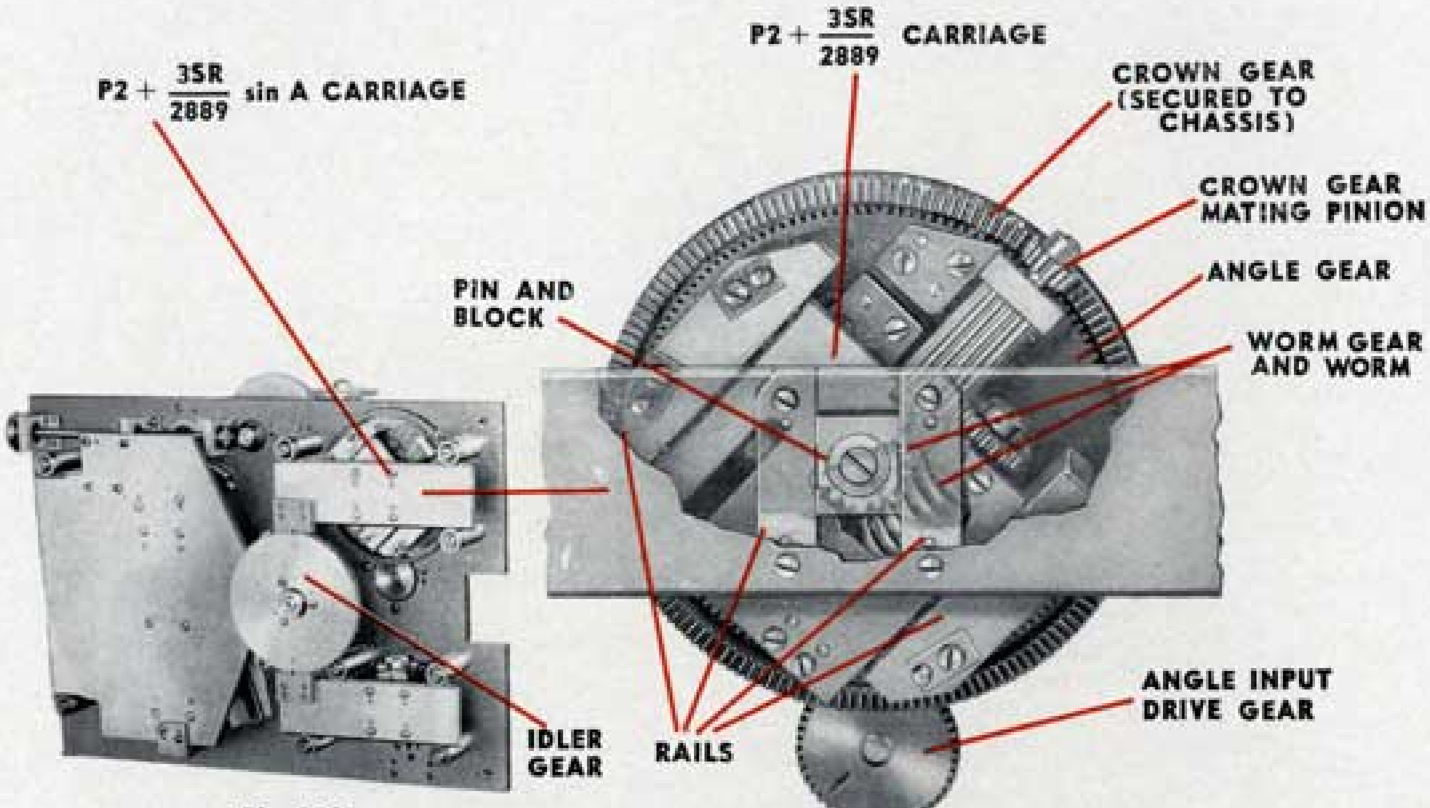


Fig. 130

Fig. 131

The linear motion of the small carriage is caused by an input which is P2+3SR/2889, this input determining the radius arm for a small pin and block. This motion is accomplished by a worm and worm gear acting as a rack and pinion, the drive for which enters through the center of the angle input gear. The angular displacement of the carriage is caused by the Target Angle input which rotates the large spur gear upon which the entire carriage assembly is mounted. The horizontal component of the motion of the pin and block is P2+3SR/2889 sin A, and is applied to the larger carriage bearing this nomenclature by means of vertically mounted rails actuated by the pin and block. This output is transferred to the large idler gear by means of a rack as seen in Fig. 130.

To prevent an angular input from changing the radius arm (hypotenuse) as set in by the P2+3SR/2889 input, a special type of differential gearing is used as can be seen in Fig. 131. The rack by which the small carriage is positioned is in the form of a worm which is geared through a sliding spur gear arrangement to a large crown gear surrounding the angle input gear and which is fixed to the chassis. When an angular input rotates the angle input gear, the small pinion which mates with the crown gear is driven by virtue of its engagement with the station-

ary crown gear, and transfers its rotation to the worm-type rack secured to the small carriage. The rotation of the worm causes a relative displacement between itself and its engaging worm wheel (hypotenuse input). Actual linear motion of the carriage within its guide rails will not occur, as this carriage travel due to worm rotation exactly offsets the travel in the opposite direction due to the rolling action of the rack about the hypotenuse input worm wheel.

If this correcting gearing were not incorporated in the unit, an angle input would change the radius arm just as was shown in the description of the Resolver Unit on Page 118, the only difference being in the arrangement of the gears which drive the radius arm carriage-positioning screw.

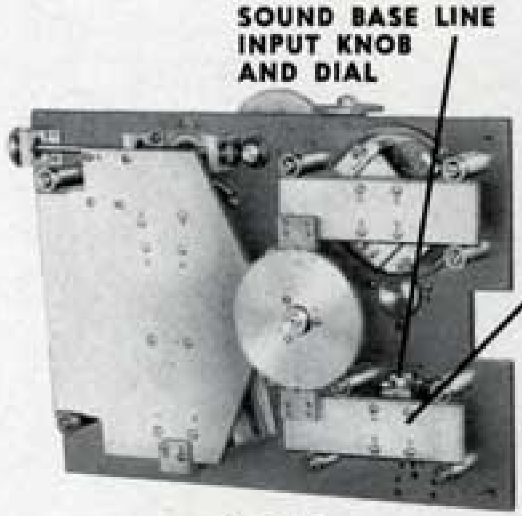


Fig. 132

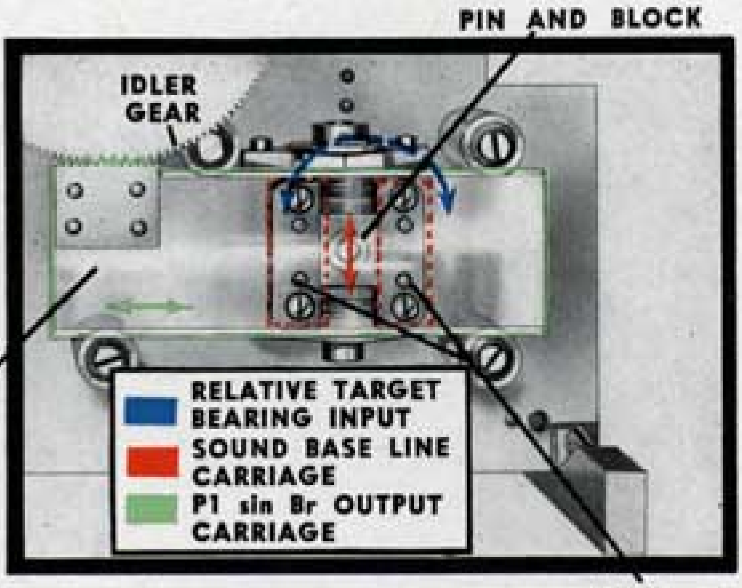


Fig. 133

The unit on the lower right, Fig. 132, is another small resolver, a phantom view of which is shown in Fig. 133.

The angular input to this resolver is Relative Target Bearing, Br, while the linear input, or radius arm of a pin-and-block assembly, is the Sound Base Line, P1. This input is set in by hand at the point indicated in Fig. 132, and need never be changed as long as the Data Computer is left on the vessel for which the Sound Base Line is set in originally.

The horizontal component of the motion of the pin and block on this resolver is P1 sin Br, which motion is applied to the P1 sin Br carriage by means of vertical rails on the carriage actuated by the pin and block. This motion is in turn transferred to the large idler gear by means of a rack as shown in Fig. 132.

The outputs of the two small resolvers just described are added mechanically at the large idler gear, mentioned in the above paragraphs, which is mounted on one end of a movable carriage, the differential action serving to position the carriage in accordance with the sum of the two functions.

This becomes the R tan (Br − Fr) input of the carriage bearing this nomenclature, and which is the third unit of the Sound Bearing Converter, as seen in Figs. 134 and 135. The other input to this unit is Range, R.

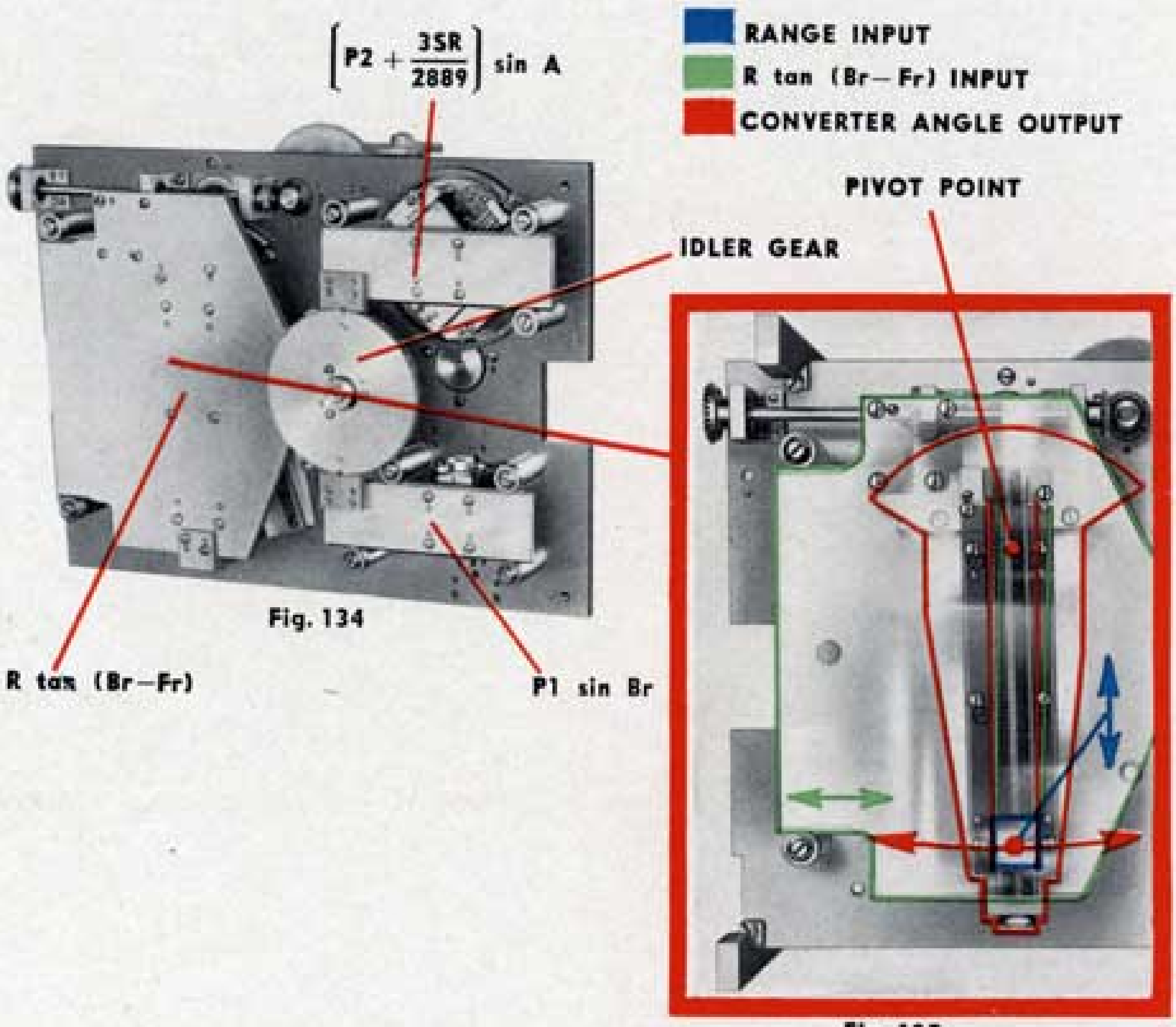


Fig. 134

Fig. 135

Turning the Range input gearing rotates a threaded shaft which positions a block sliding between two parallel rails affixed vertically to the inner face of the tangent carriage. A pin projecting from this sliding block carries another sliding block which is located between another parallel set of rails affixed to the inner face of an arm which is pivoted at its upper end as shown in Fig. 135. This arm carries a sector gear on its upper end which meshes with an output gear, the output being the Converter Angle, Br − Fr. The Range is limited to values between

300 and 8000 yards in the Sound Bearing Converter by a Stop on the rear of the Position Keeper chassis, Range Stop, Fig. 97, Page 106.

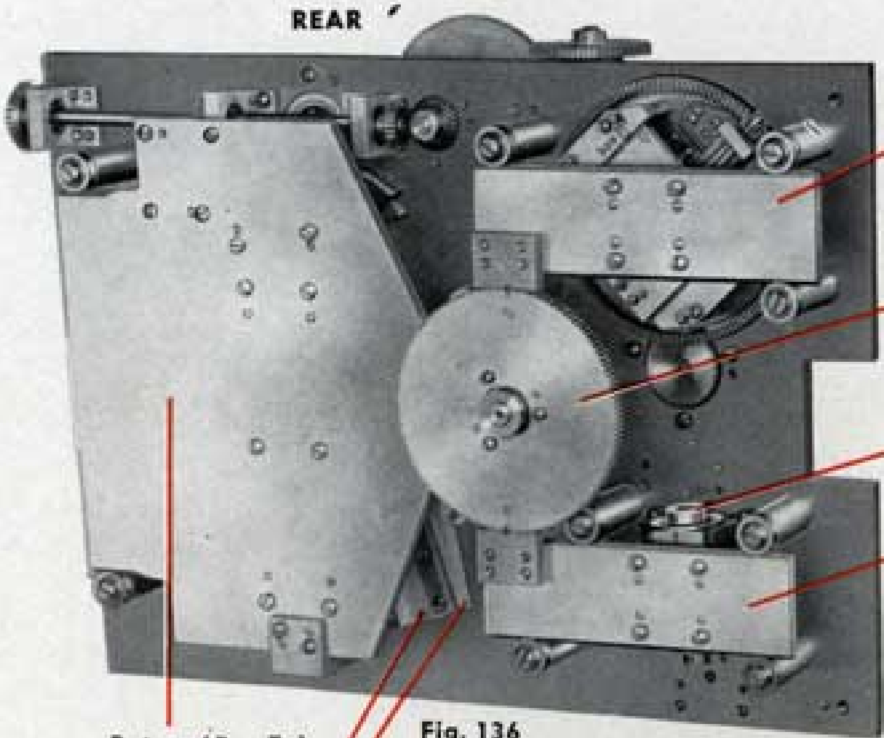


Fig. 136

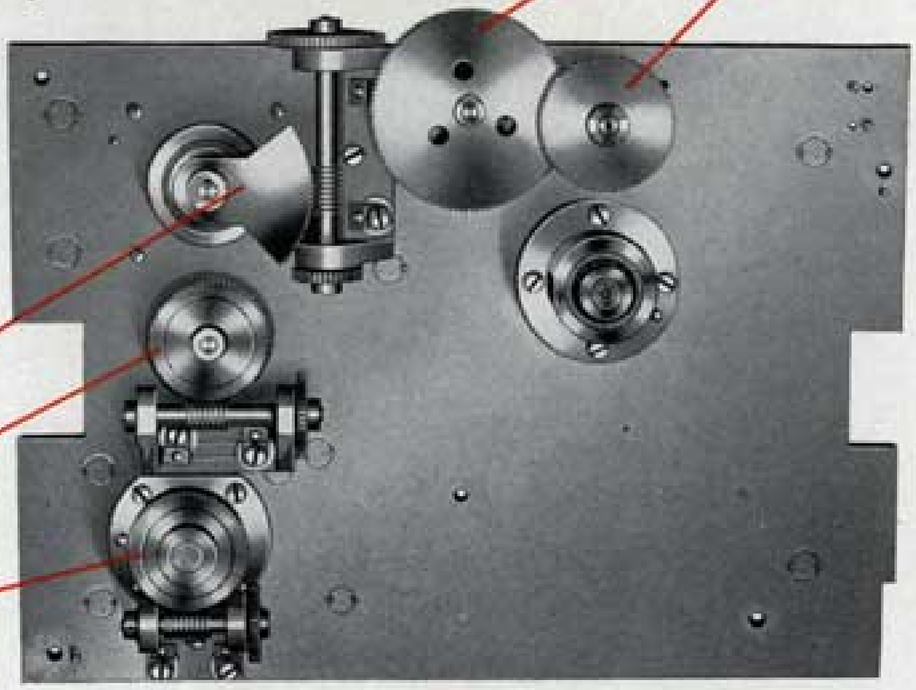


Fig. 137

The Sound Bearing Converter is secured to the rear of the Position Keeper chassis by five screws.

CAM UNIT

REAR, TOP AND LEFT

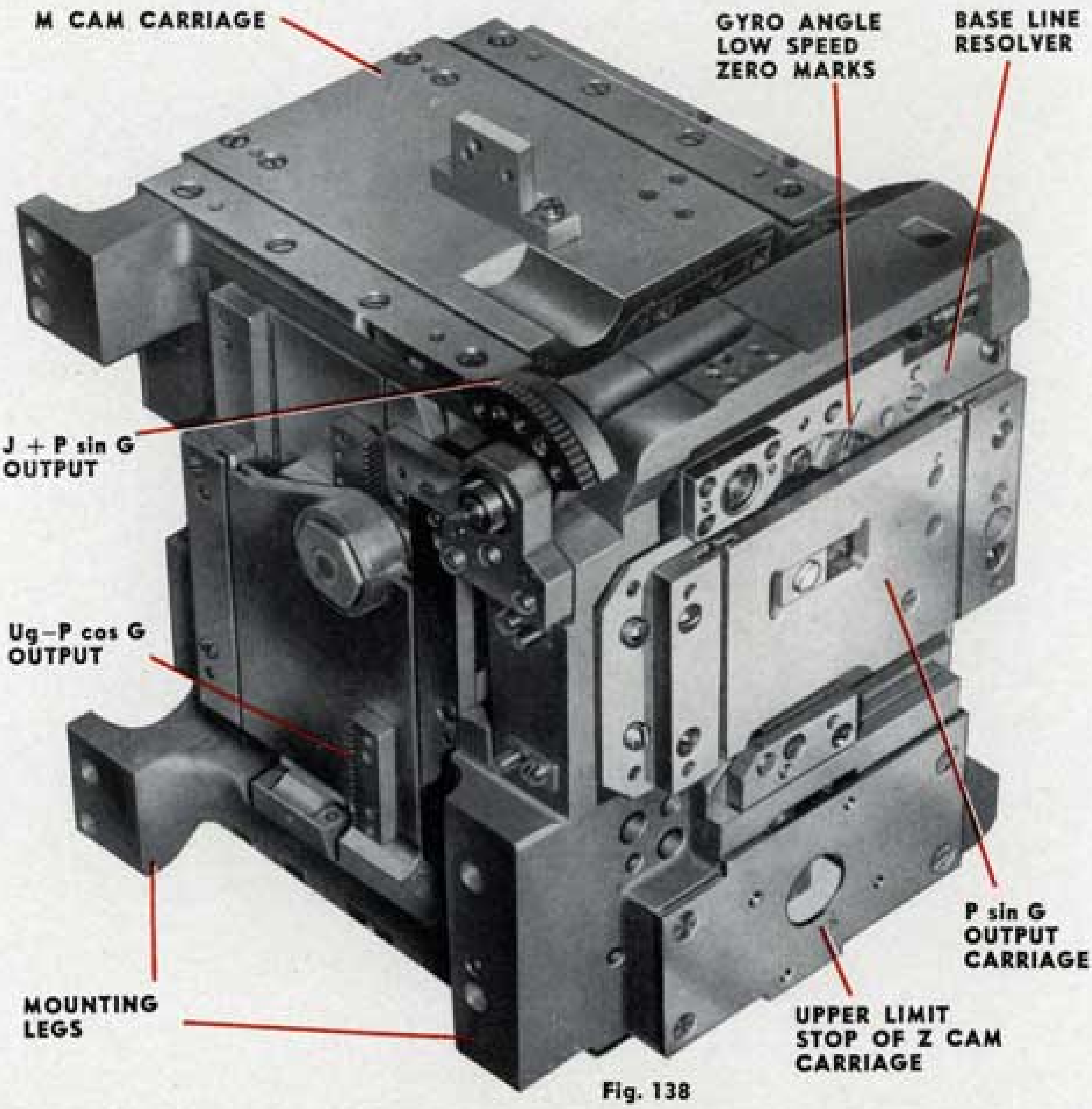


Fig. 138

The fwd and aft Cam Units are identical in construction with the exception that the fwd unit has a small bracket mounted on the upper left side which supports the Uy input gearing to both Angle Solver mechanisms. The following general description applies to either.

Included in each Cam Unit are four cams, four differentials and the Base Line Resolver. All of these parts are mounted on one box-like chassis approximately 9 inches high, 9 inches wide and 7½ inches deep. This chassis is an aluminum casting and is mounted on the main Angle Solver chassis by means of lugs which are integral parts of the casting. See Fig. 138.

FRONT, BOTTOM AND RIGHT

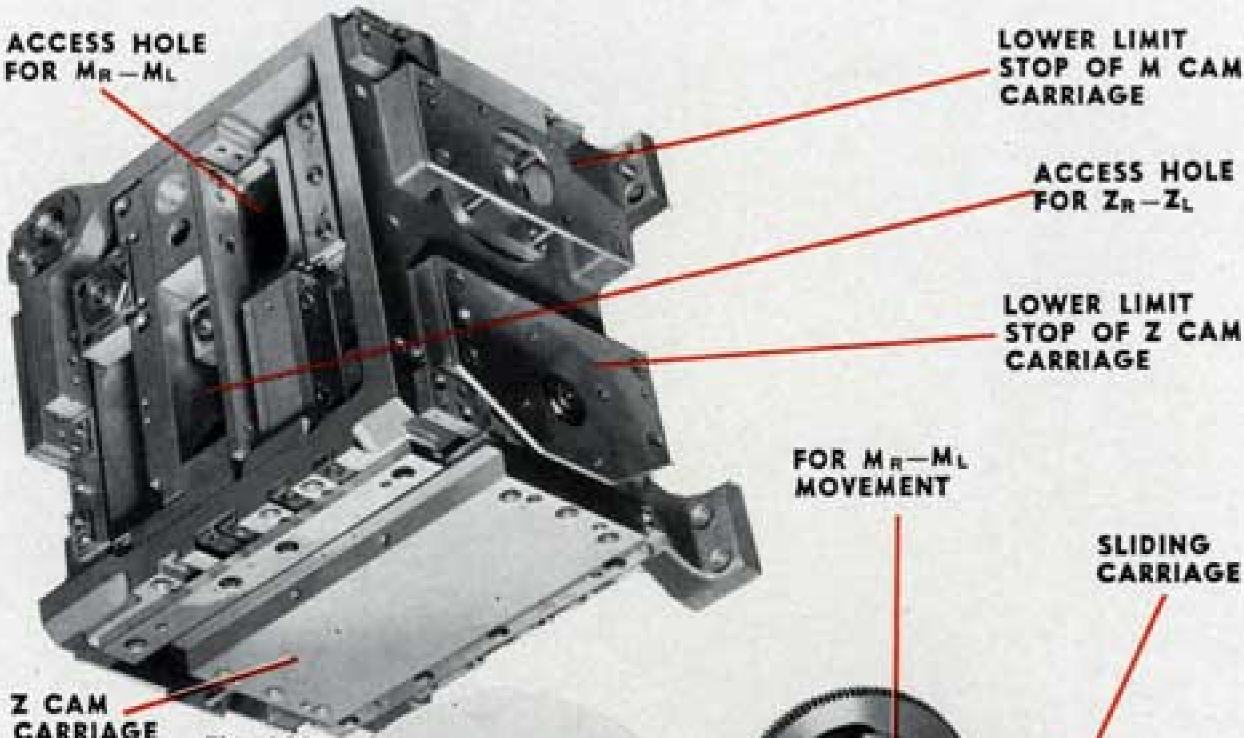


Fig. 139

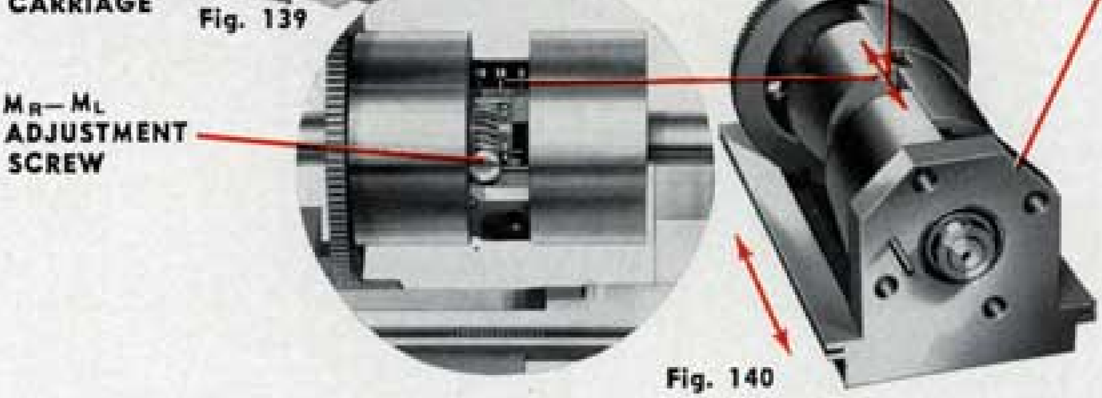


Fig. 140

All cams are three-dimensional, two being a function of G and Z, and two a function of G and M. In addition, they are split on their 0-180° axial plane so that they may be set for different values of Z and M for corresponding right and left Gyro Angles.

The two M Cams are mounted on a common shaft which is held in a sliding carriage, see Figs. 139 and 140. This is to allow the cams to be moved in an axial direction with respect to their followers. The rails for guiding the carriage are on the top of the chassis, as shown in Fig. 138, and are of the V-groove and straight ball bearing type.

The two halves of the M Cams which are displaced by the M_R-M_L adjusting screw are joined by two bars, one of which carries a scale, graduated every 10 yards to indicate the value of M_R-M_L. In addition, the periphery of the pinion which meshes with the rack mounted between the two cams, is graduated every yard to indicate M_R-M_L.

The Z Cams are similarly arranged, and the same adjustment mechanism is provided in the Z Cam assembly for changing and indicating the value of Z_R-Z_L.

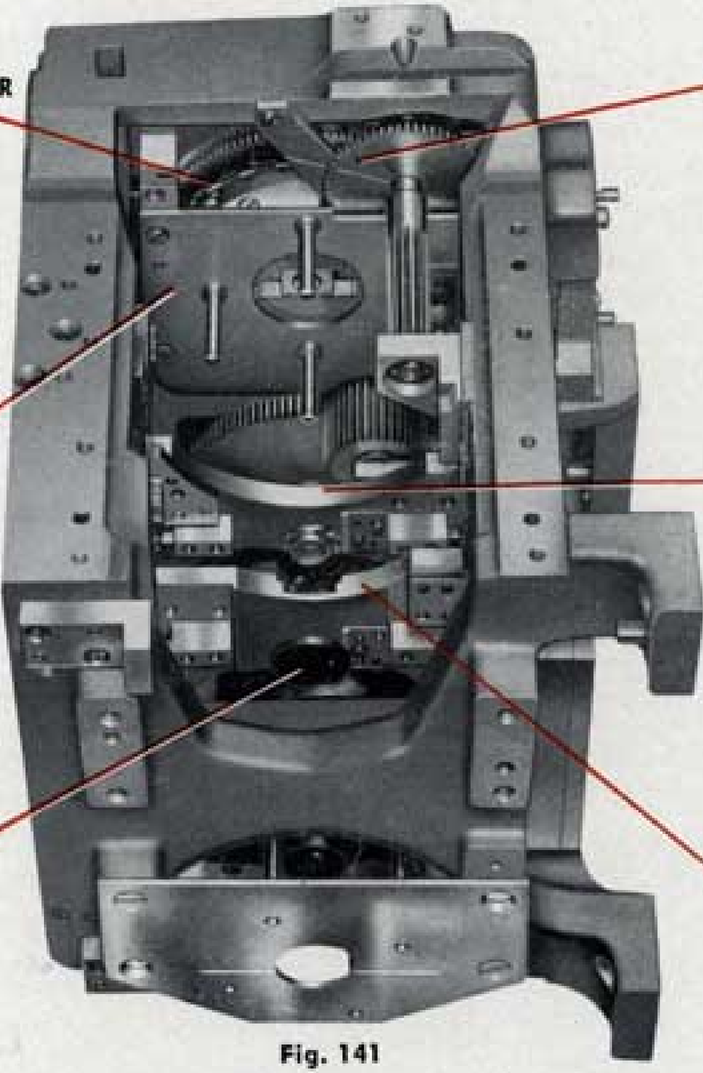


Fig. 141

The two Z Cams are mounted on a similarly constructed carriage guided by rails on the bottom of the chassis, Fig. 139, Page 137. The adjustment screws for moving one half of each cam axially with respect to its other half are located between the two cams on each shaft. This adjustment is performed with a screw-driver, access holes being provided in the assembly as indicated in Fig. 139, Page 137.

In Fig. 141 the M Cams have been removed to show an internal view of the Cam Unit. Two cam follower carriages are visible—the two which are actuated by the Z Cams. The Z Cam followers are above the cams, as shown, but those for the M Cams are below their respective cams. However, the cams are cut so that an upward movement of any follower corresponds to an increasing value of cam output, in a positive sense.

Cam followers are guided by rails on the front and back of the chassis and are held against the cams by coil springs.

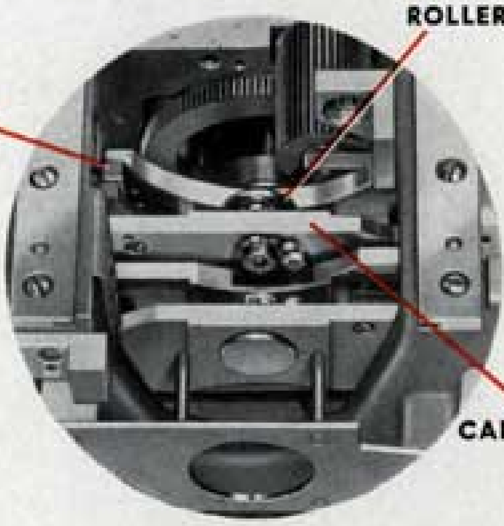


Fig. 142

Fig. 142 shows the construction of one of the cam follower carriages. With but minor exceptions, all cam follower carriages are alike.

Two of the differentials previously referred to as a part of the Cam Unit are used to add the outputs of two pairs of cams, while two other differentials combine these results with outputs of the Base Line Resolver. All differentials are of the sliding rack type as described on Page 38 under Fundamentals, and are employed as follows:

Each cam follower carries a rack which, when connected through the idler pinion to the rack on another follower forms a differential which adds the outputs of two cams. See rack and pinion differential theory on Page 38.

The outputs of the upper and lower cams on the right end of the Cam Unit are $M(1-\cos G)$ and $Z(\pi G/180-\sin G)$ respectively and when added by a differential (located on the right side of the back of the chassis) their combined output is the quantity Ug. Similarly, the outputs of the upper and lower cams on the left end of the Cam Unit are $M \sin G$ and $Z(1-\cos G)$ respectively and when added by a differential (located in the center of the front of the chassis) their combined output is the quantity J.

M and Z are limited by the stop pins which contact the ends of the cams. These pins are fixed to the Cam Unit frame and project toward the cams in a direction parallel to the cam axis.

The Z Cam carriages of the Cam Units are joined by a bar which carries a rack to take the Z input simultaneously; the M carriages of both Cam Units are also joined by a bar which carries a rack to which the M input is applied. Refer to Fig. 144, Page 141.

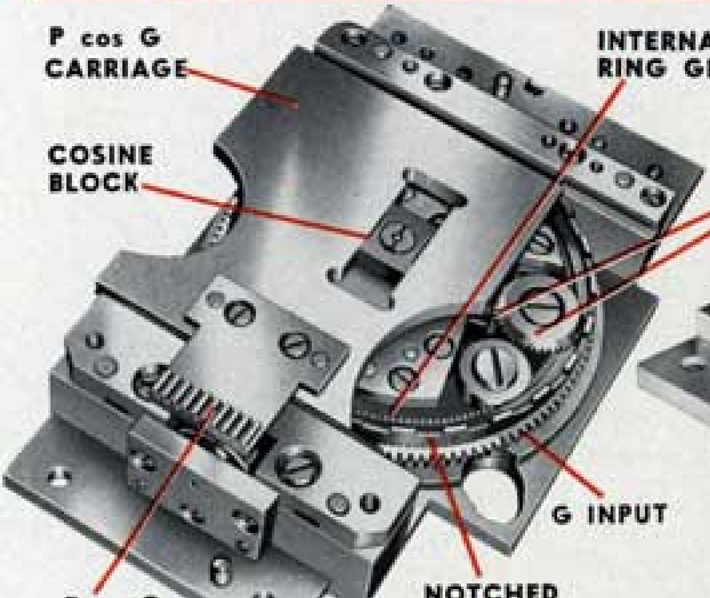


Fig. 143A INSIDE

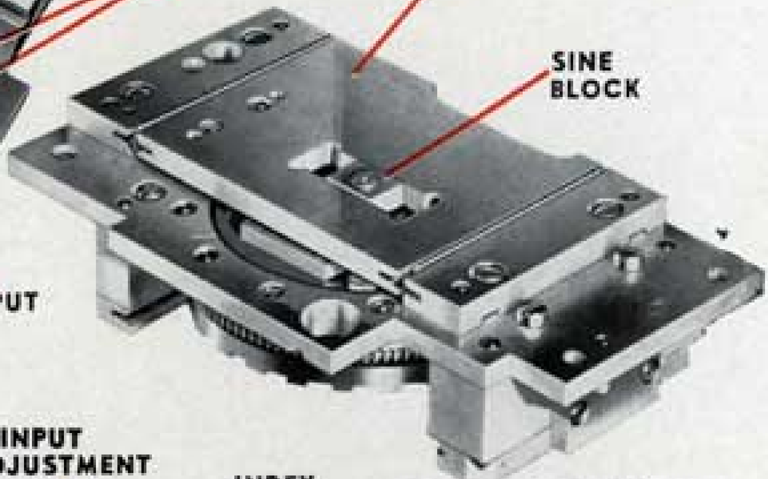


Fig. 143B OUTSIDE

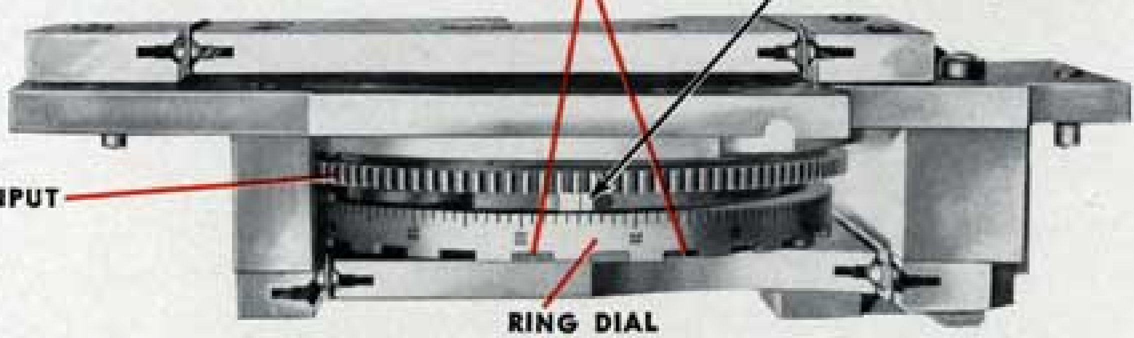


Fig. 143C

The Base Line Resolver, Figs. 143A, 143B and 143C, is bolted to the left end of the Cam Unit as shown in Fig. 138, Page 136. It works on the same principle as the Resolver Unit. See gear diagram on Page 93A. The two sliding blocks for the sine and cosine carriages are positioned by the input P. This input is made by turning a notched dial, see Fig. 143A. The notched dial is integral with an internal ring gear which meshes with a small pinion. The pinion transmits the P input to the carriage-positioning blocks through a pair of bevel gears which drives one of two threaded shafts. This shaft positions the cosine carriage block. Fastened to this shaft and meshing with a gear on a similar shaft is a helical pinion. The second shaft, which is at right angles to the first shaft, positions the block for the sine carriage. The two carriages are connected to rack gears which send the $P \cos G$ and $P \sin G$ outputs to the Cam Unit.

In the Cam Unit, $P \sin G$ is added to J by a differential mounted on the front of the chassis on the left side, and the output, $J + P \sin G$, is converted to rotary displacement by a rack and pinion at the upper left front corner of the chassis. This output is received from a spur gear located on this shaft at the upper left rear corner of the chassis, as seen in Fig. 138, Page 136.

Likewise, $P \cos G$ is subtracted from Ug by a differential mounted on the back of the chassis near the center, and the output, $Ug - P \cos G$, is taken off the rack located in the center of the back of the output carriage. See Fig. 138, Page 136.

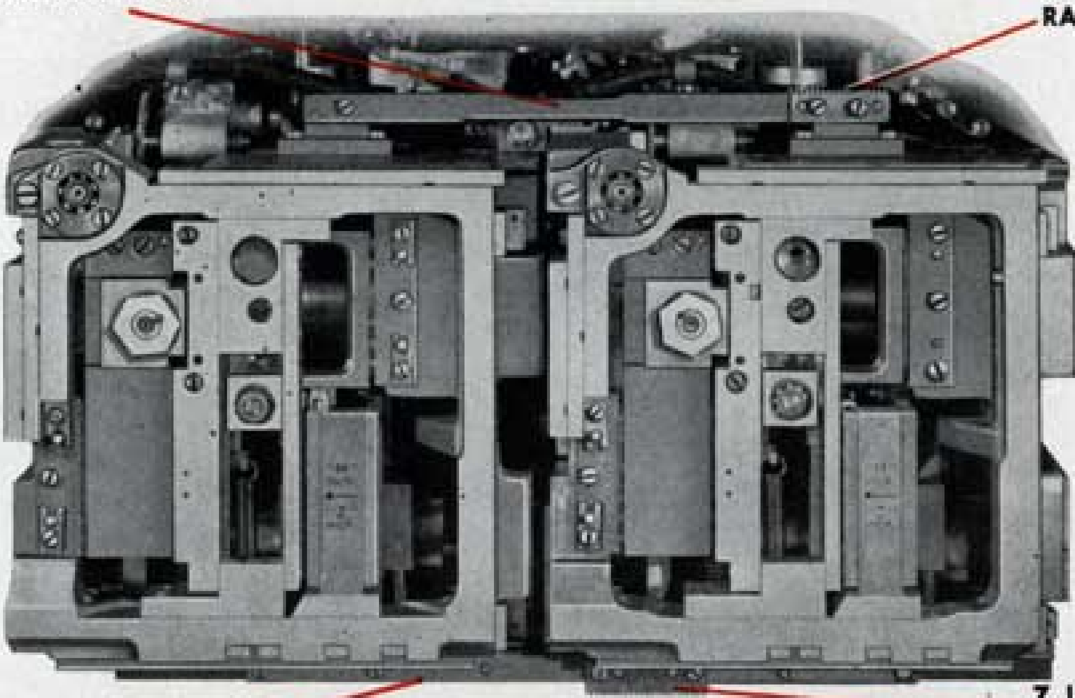
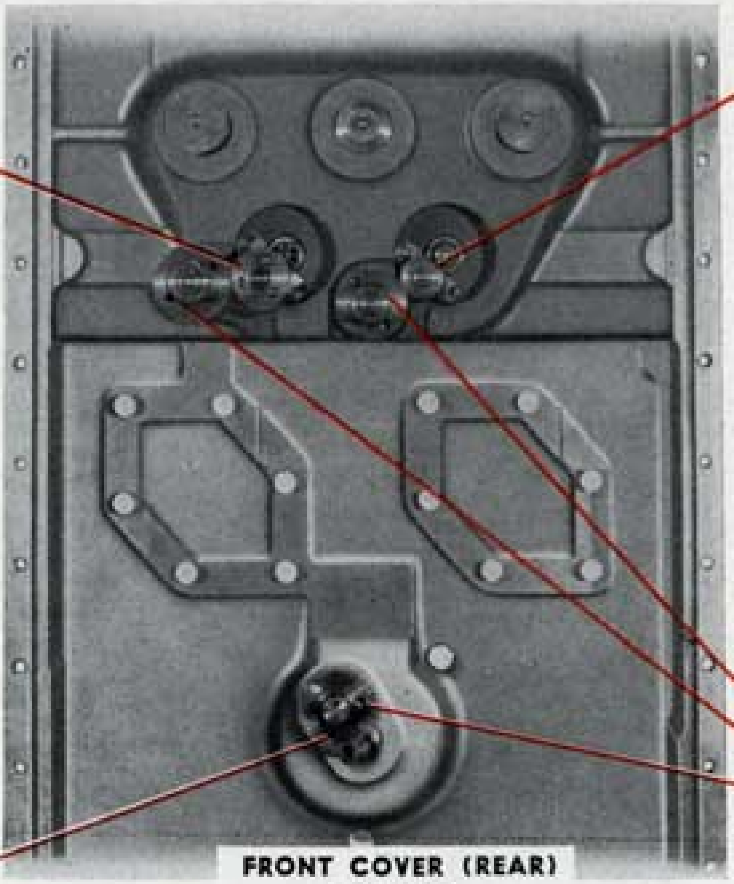


Fig. 144

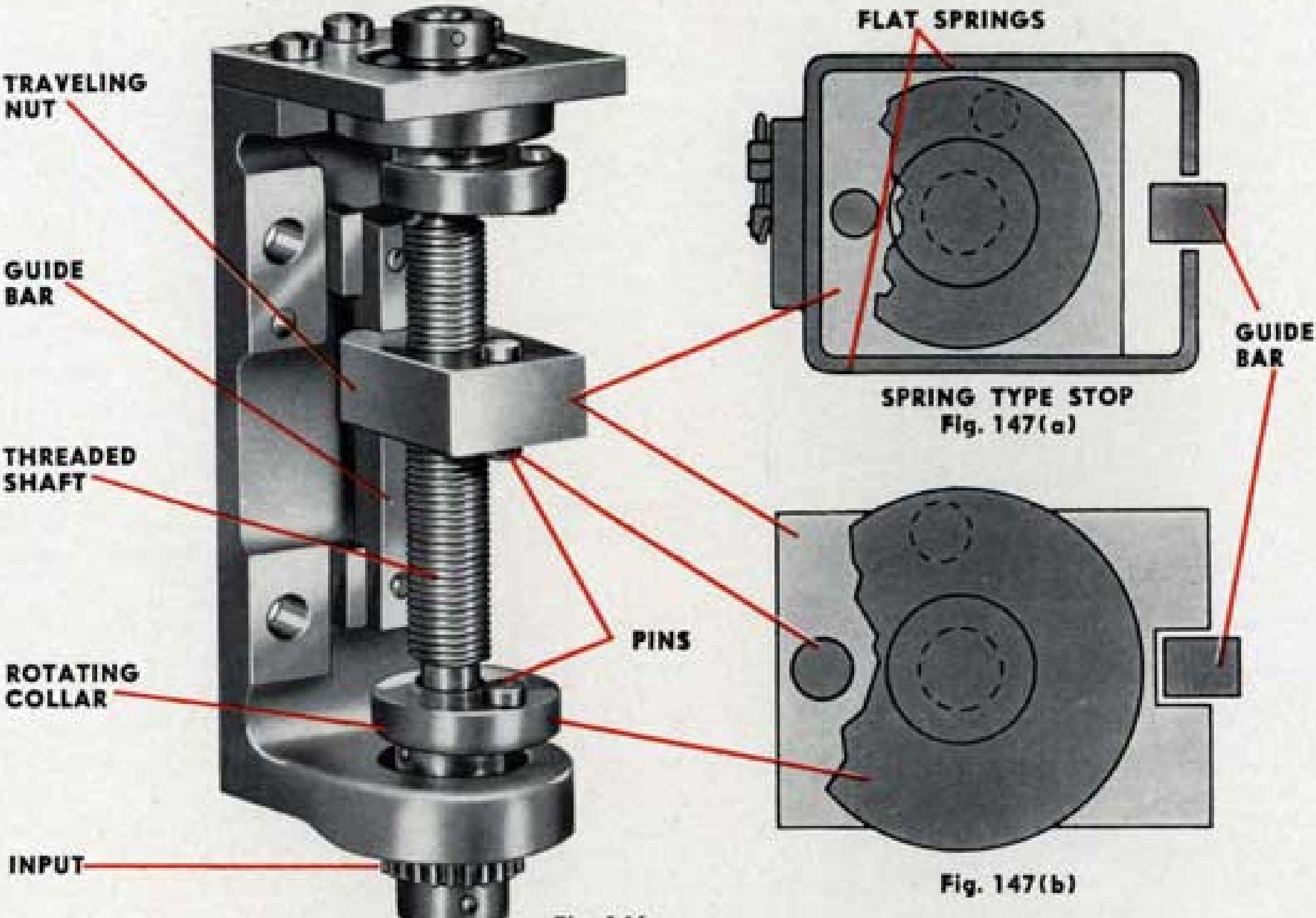
Each of the two input racks Fig. 144 is driven by gearing in the back of the front cover of the Angle Solver, the gearing in turn being actuated by hand knobs in the front of the cover. See Fig. 145. The Uy gearing, which is also actuated by a hand knob on the front of the cover, is connected to the output of the Proportionator Unit shown in Fig. 116, Page 121, through a differential of the type shown in Fig. 30, Page 41.



FRONT COVER (REAR)

Fig. 145

STOPS, Traveling nut type



SPRING TYPE STOP
Fig. 147(a)

Fig. 147(b)

Fig. 146

With but minor variations, all Stops in the Data Computer are constructed alike and work on the same principle. The basic construction is shown in Figs. 146 and 147.

A Stop of this type consists of a traveling nut which is prevented from turning by means of a guide bar which engages a slot in the nut. As the threaded shaft is rotated, the nut travels toward one end or the other until it approaches the rotating collar so closely that its Stop pin blocks further motion of the Stop pin or dog on the rotating collar. Thus, further rotation of the input shaft in that direction is prevented.

The same thing occurs at the other end of its travel, and by proper gear ratios the length of travel of the Stop can represent any desired value or quantity of any function.

Stops on motor-driven inputs are equipped with springs which act as guides, as shown in Fig. 147A. This construction is designed to prevent damage to the connecting gearing when the Stop acts with the motor running at full speed. The principle of operation is exactly as in the slotted nut type.

CONSTRUCTION

FOLLOW-UP HEAD

Fig. 148 shows the exterior construction of the 4-ring follow-up head. The body is a phenolic molding, while the collector rings (as well as the rollers and segments inside the unit) are made of a metal whose oxide does not interfere with current flow.

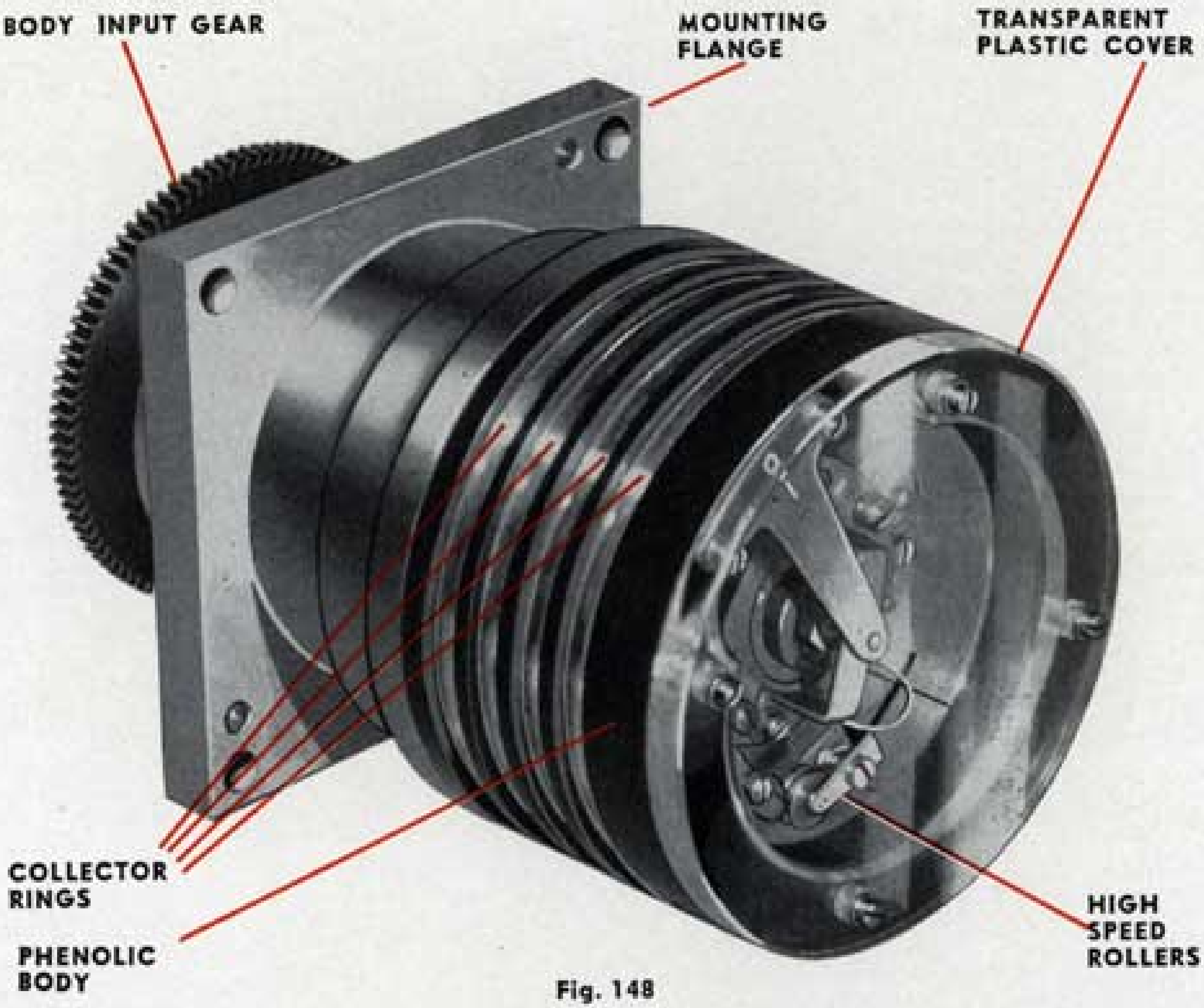


Fig. 148

The contact rollers are mounted in trolley assemblies and spring loaded so as to exert a uniform pressure on the ring segments. The high speed roller consists of two rollers in tandem with a spacing adjustment for controlling the sensitivity of the follow-up action, this construction and the adjusting screws being shown in Fig. 149, Page 144.

Fig. 150 is an exploded view of the 4-ring follow-up head, showing the relative location of the various parts.

A transparent plastic cover protects the interior of the unit against dust and oil. The follow-up head is secured to the chassis of the instrument by means of four screws which pass through a flange and into

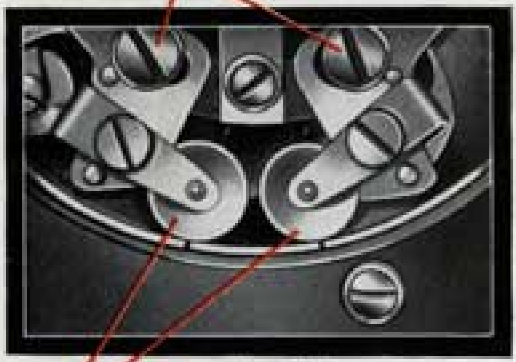


Fig. 149

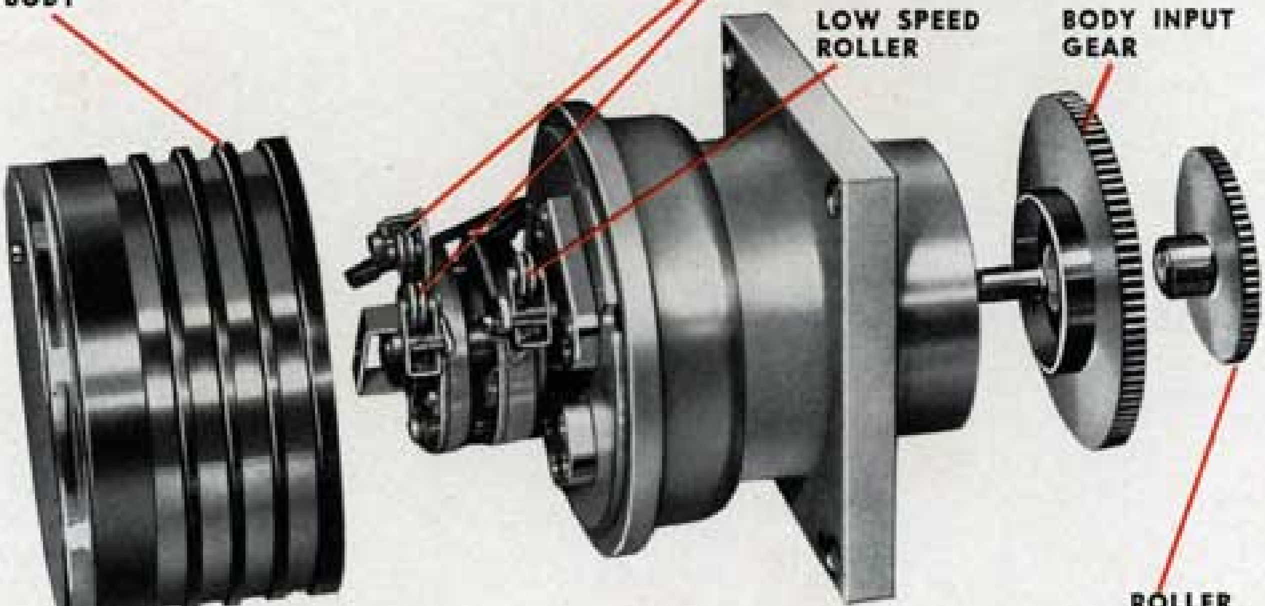


Fig. 150

tapped holes in the chassis. All electrical connections are made through brushes or rollers which contact the slip rings when the follow-up head is in place in the instrument.

DISASSEMBLY AND REASSEMBLY

Occasionally it is necessary to disassemble either or both of the two sections of the Computer. When this is to be done, along with subsequent reassembly, the procedures outlined in the following section should be used.

SECTION 5

REMOVAL OF INSTRUMENT FROM BULKHEAD AND SEPARATION OF CASES.

It is possible to remove either the Position Keeper or Angle Solver chassis from its case without removing the instrument from the bulkhead and separating the cases. As this would be done only in an emergency, the procedure for disassembling and reassembling the instrument is written for the usual method of separating the cases and removing them to the repair ship for disassembly. Steps 1 through 12 are instructions for separating the two sections of the instrument.

1. Disconnect the wiring from the terminal blocks in the electrical compartment at the top of the Angle Solver.

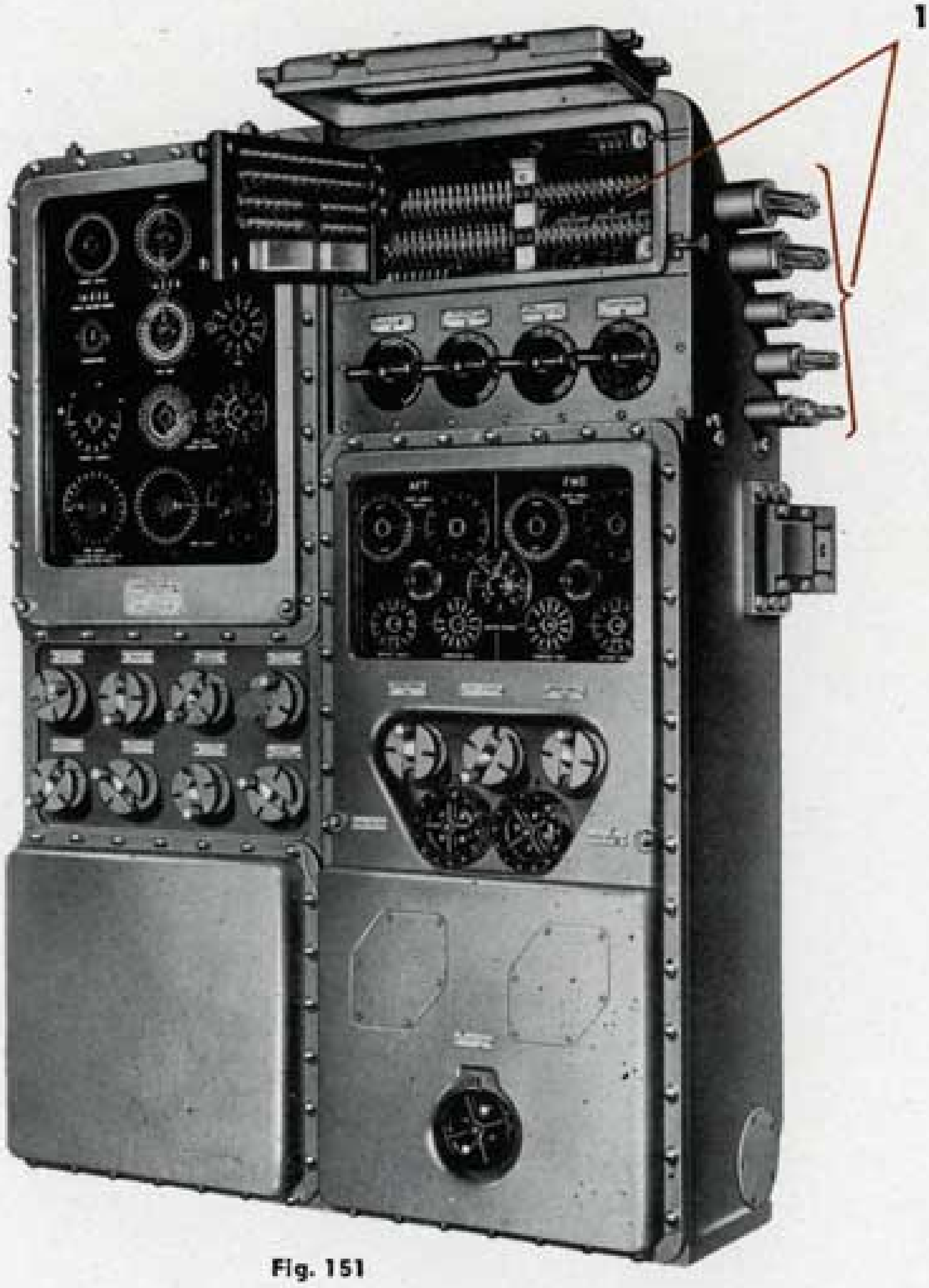


Fig. 151

2. Remove the instrument from the bulkhead, (eighteen bolts at bottom, one bolt on each side).

3. Remove the two large securing bolts at the back of the two sections.

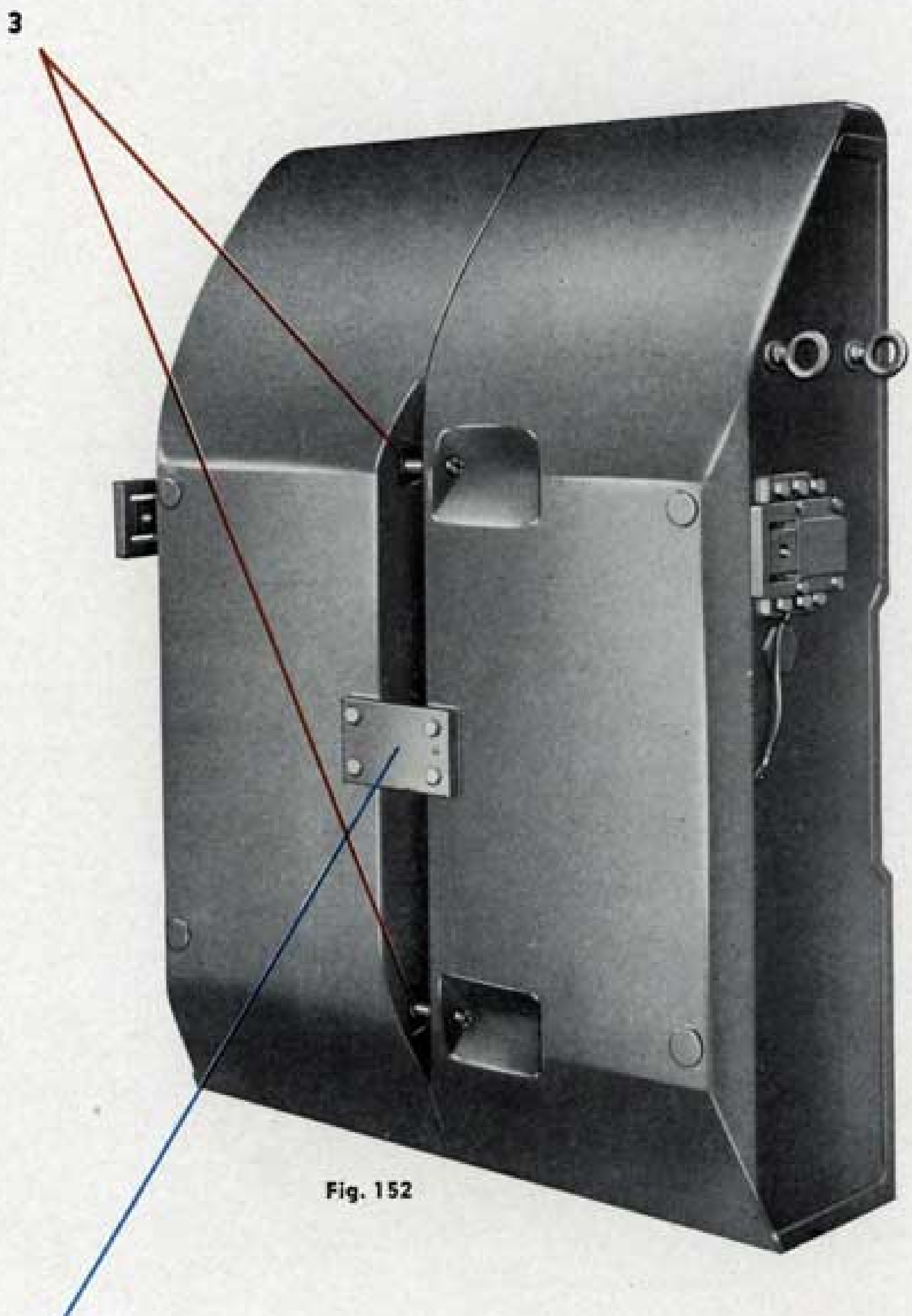


Fig. 152

4. Remove the short plate at the back of the instrument.

5. Remove the front covers.

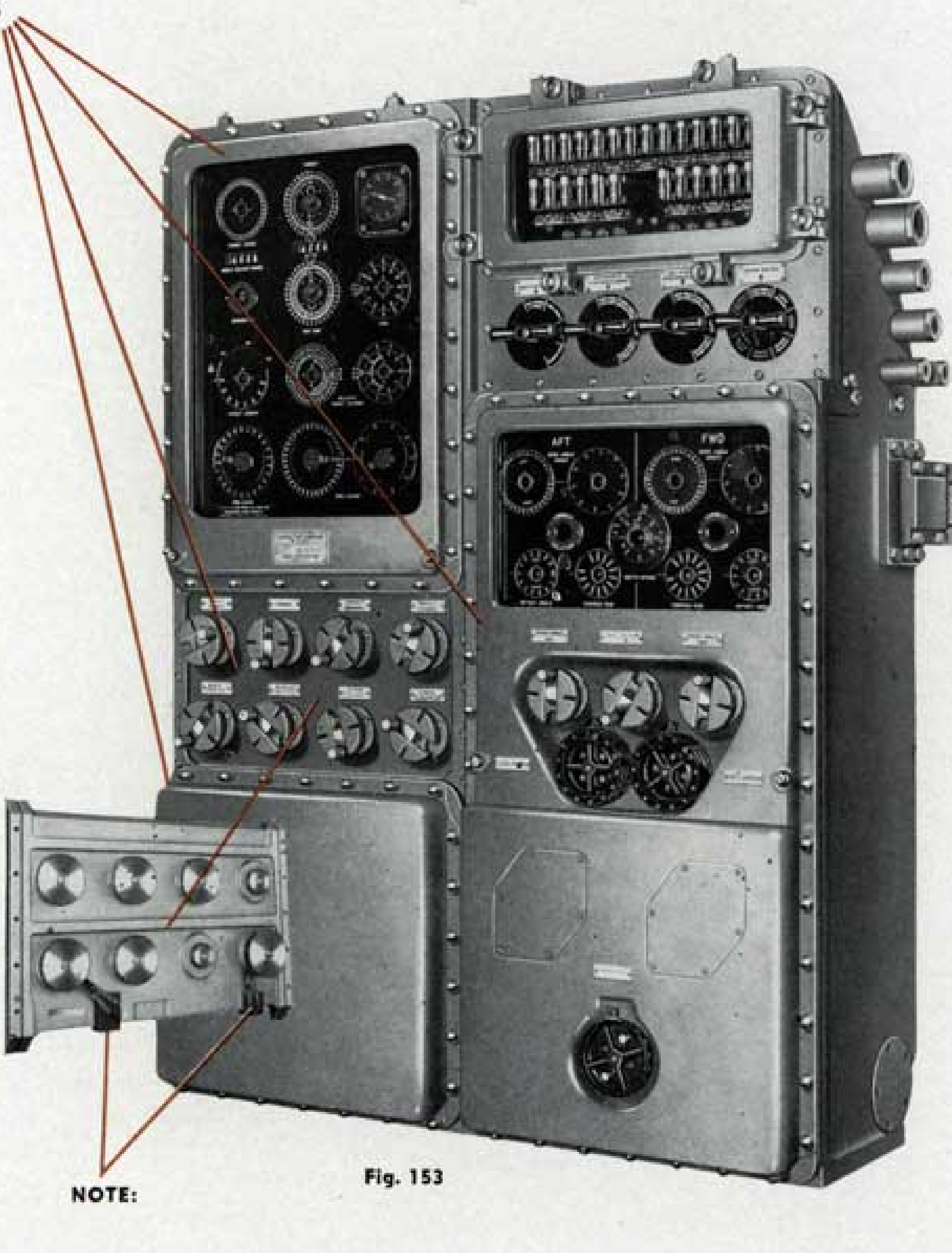


Fig. 153

NOTE: In removing the middle cover from the Position Keeper case, it will be found necessary to disconnect the wiring from the two switches on the back of the cover after it has been removed several inches from the case.

DISASSEMBLY AND REASSEMBLY

6. Remove the bolts which secure the large connecting plate to the bottom of the two sections.

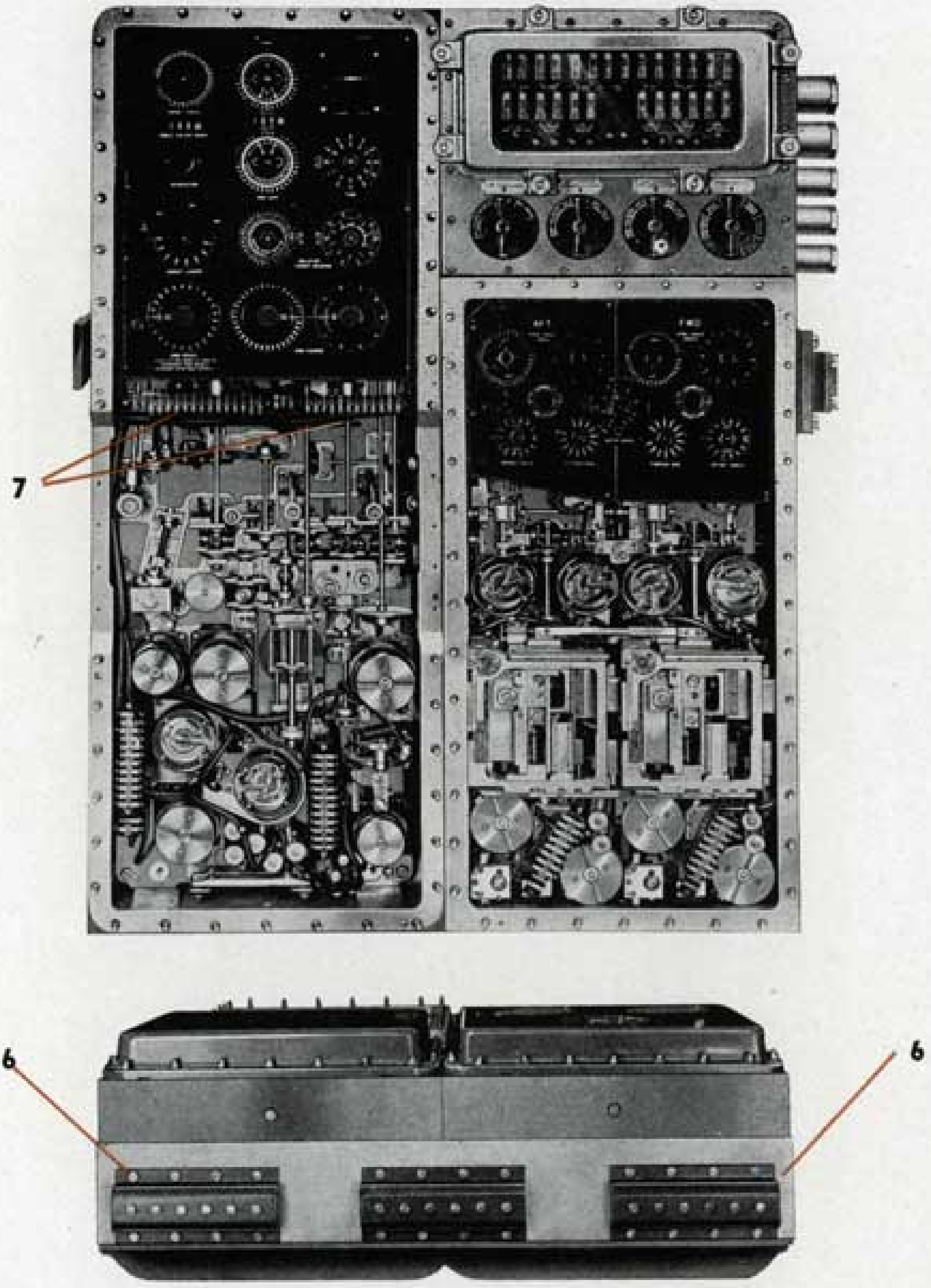


Fig. 154

7. Disconnect any electrical cables in the Position Keeper which would hinder separation of the two sections.

8. Remove the dial index plate from the Position Keeper, (two slip dowels and eight screws).

9. Remove the upper of the three large securing bolts.

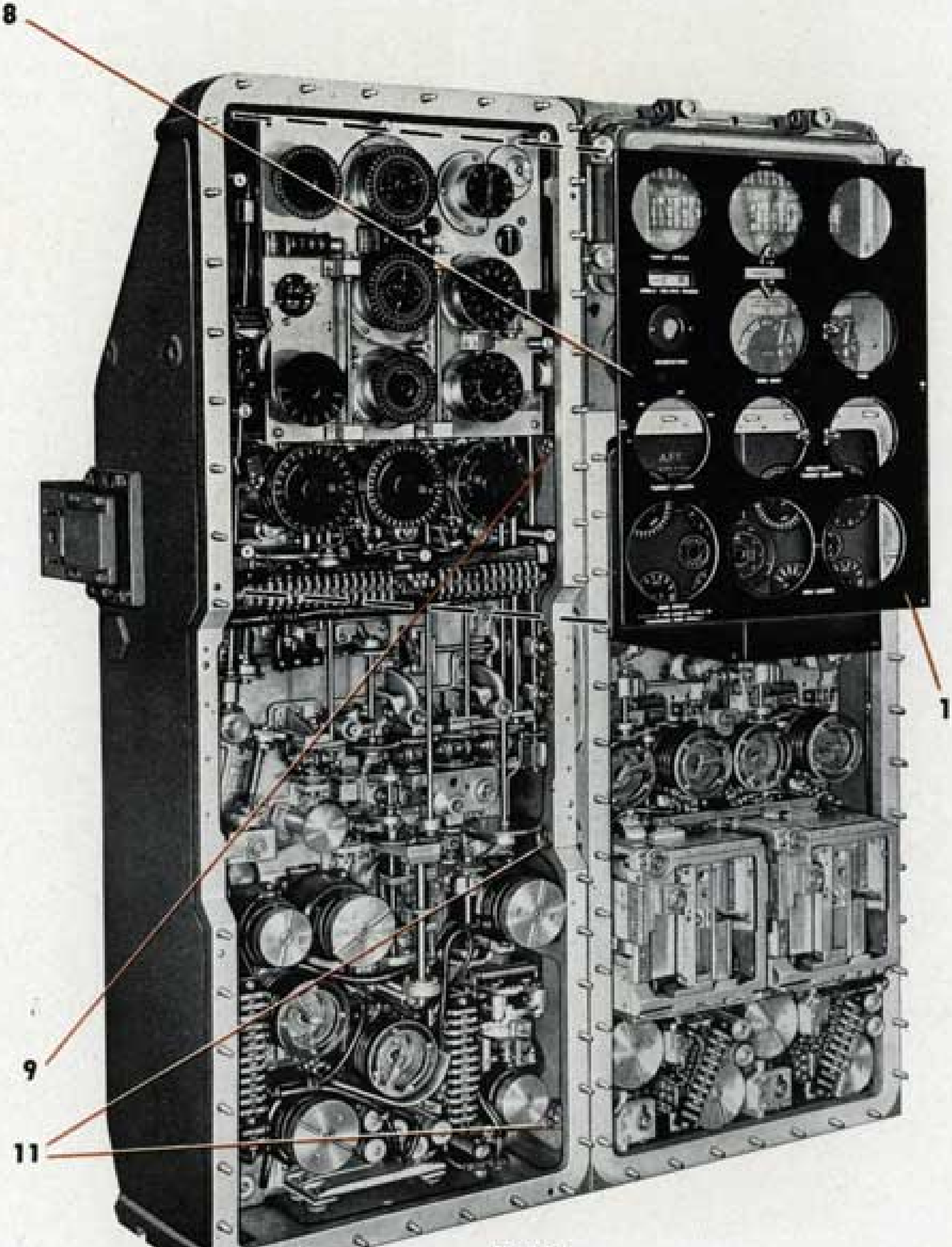


Fig.155

10. Replace the dial plate temporarily.

11. Remove the lower two large securing bolts.

12. Carefully separate the two sections. This should be done with the instrument standing vertically and resting on the large bottom connecting plate. This plate and its associated key, which fits into the bottom of the two sections, will serve as a guide during the separation.

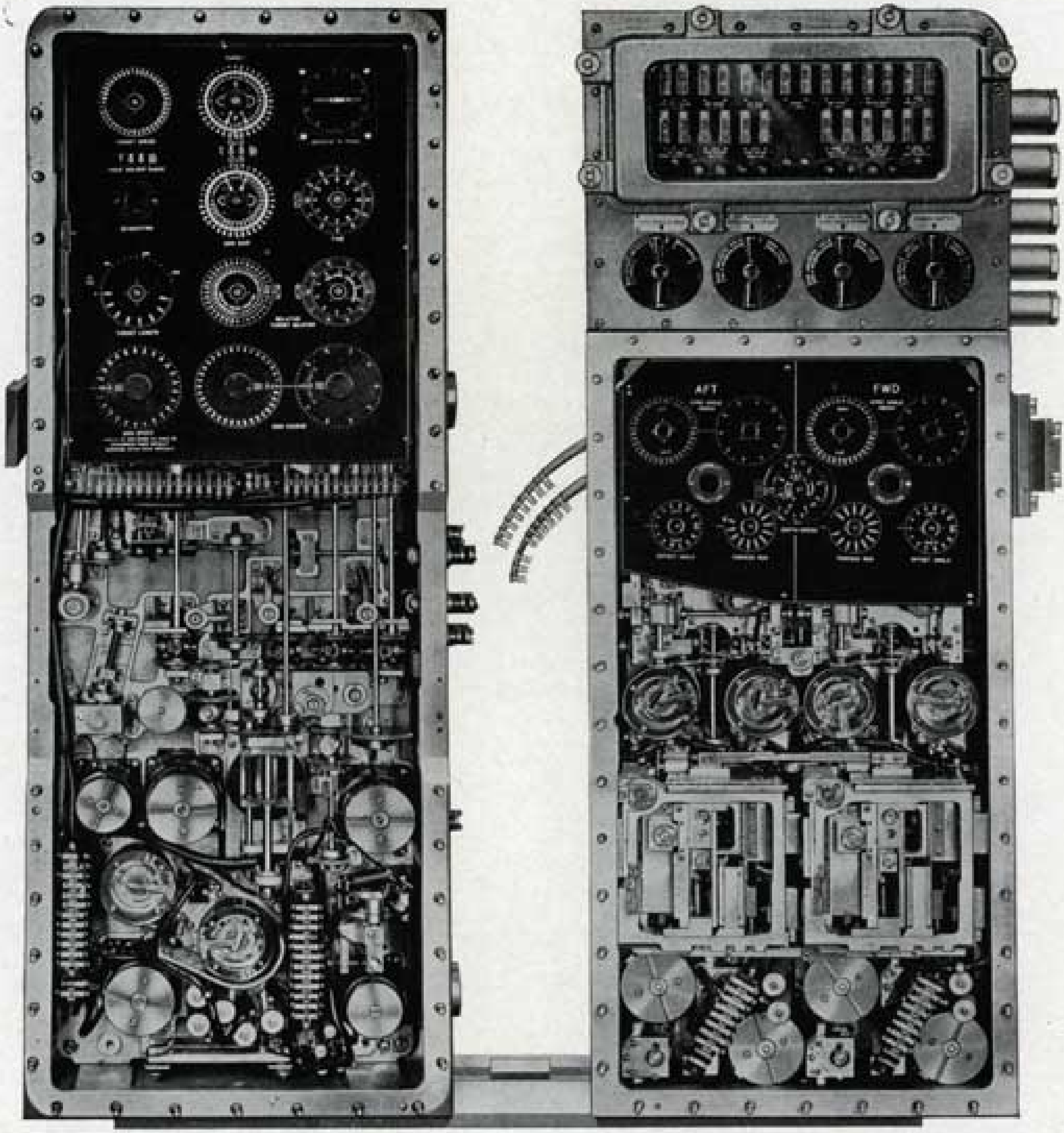


Fig. 156

The sections may now be worked upon separately as desired, and each chassis may be removed from its respective case in the manner subsequently outlined.

REMOVAL OF POSITION KEEPER CHASSIS FROM ITS CASE

13. All wiring which would otherwise hinder the removal of the chassis must be disconnected.

*NOTE: It is essential that the slip dowels be removed before the screws, otherwise the removal of the slip dowels might be extremely difficult due to the weight of the chassis which would be imposed directly on the two dowels.

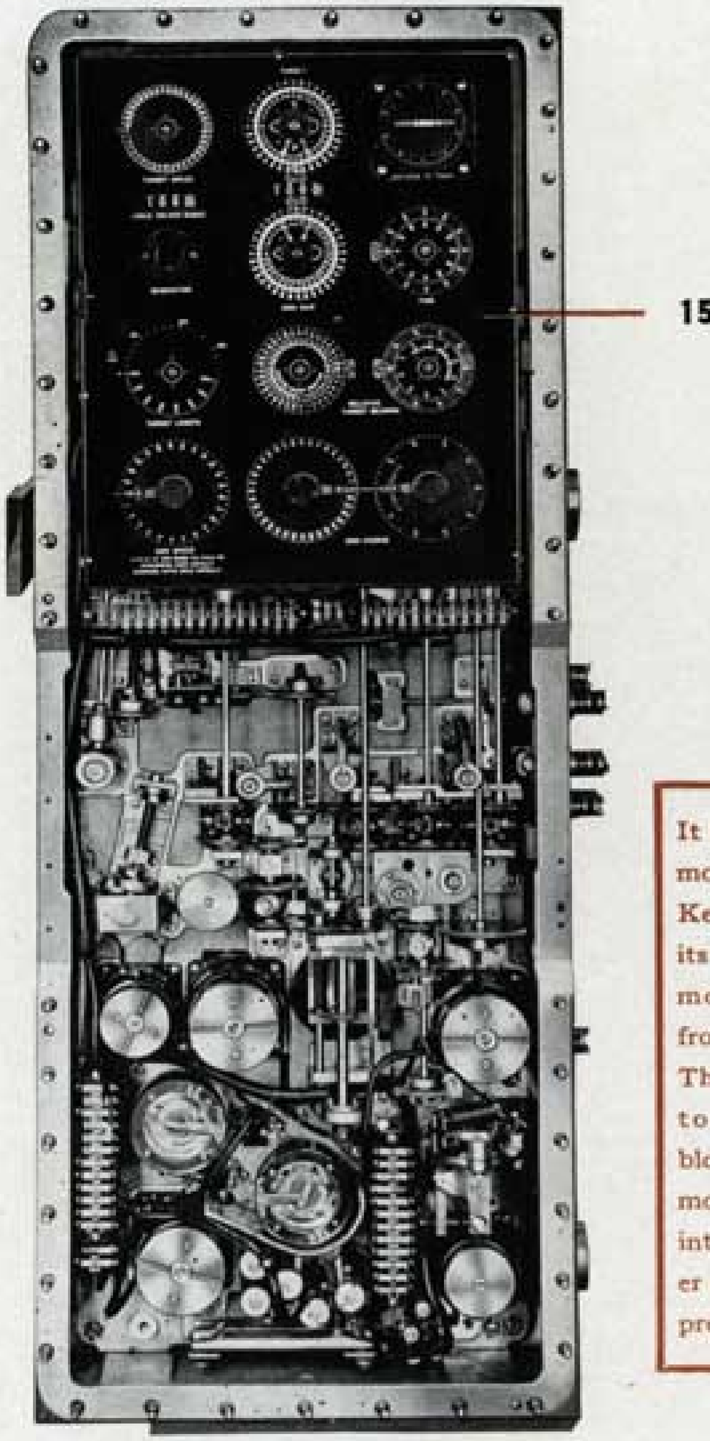


Fig. 157

It is possible to remove the Position Keeper chassis from its case without removing the case from the bulkhead. The electrical cable to the terminal block must be removed and pushed into the Angle Solver case. Otherwise, proceed as noted.

14. Set the Angle on the Bow to 135 deg. Port, and the Relative Target Bearing to 135 deg.

15. Remove the dial index plate again. Remove the two slip dowels and the eight screws which secure the chassis to the case, See Note.*

16. It is necessary to disconnect all wiring which would otherwise hinder removal of the chassis from the case.

17. The plate supplied by the repair ship should now be secured to the bottom flange of the Position Keeper case.

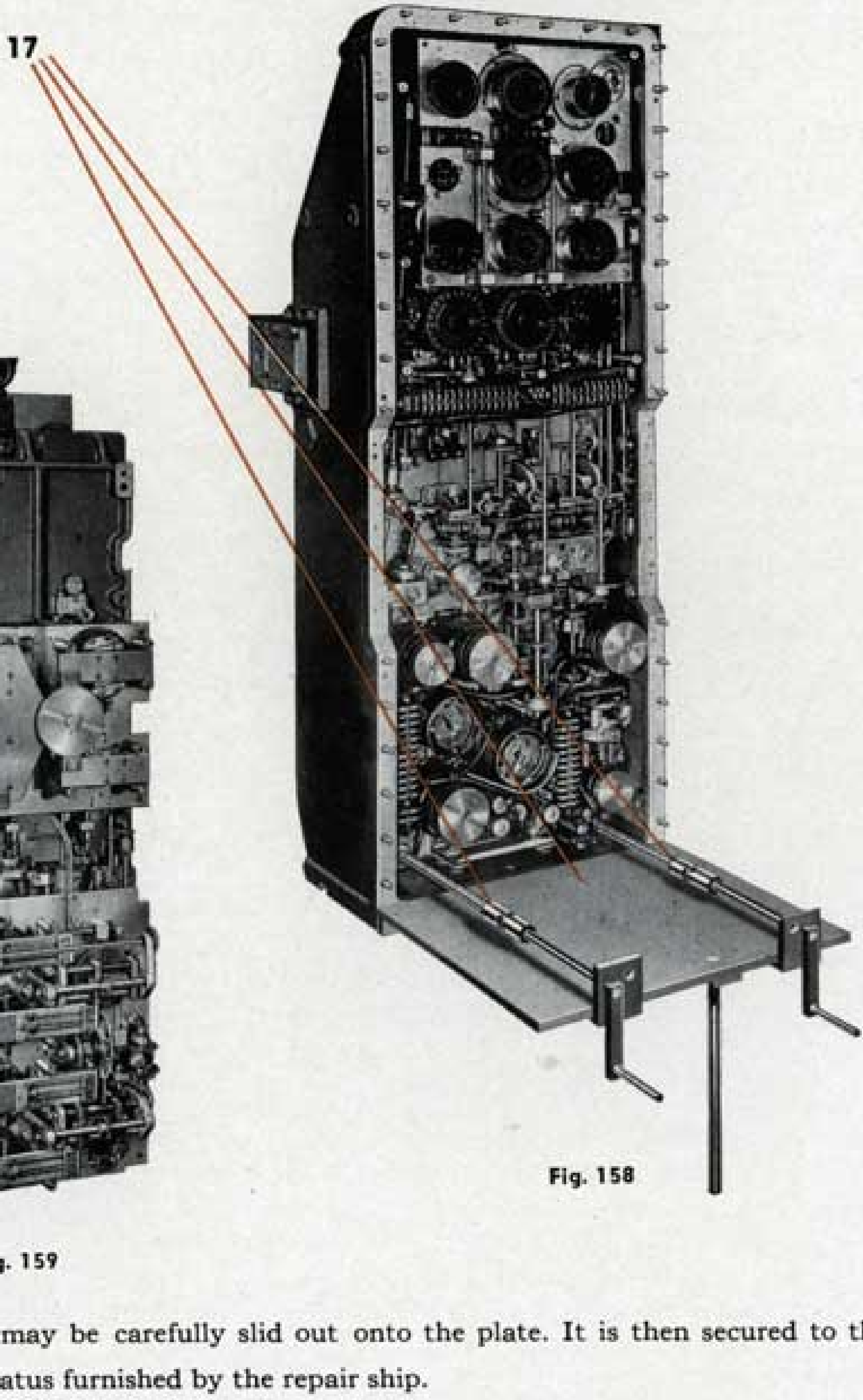


Fig. 158

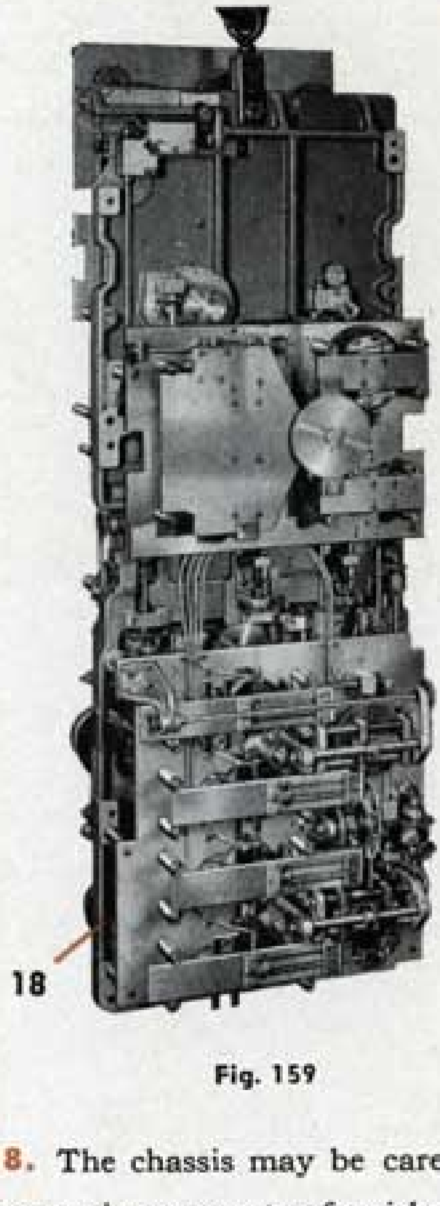


Fig. 159

18. The chassis may be carefully slid out onto the plate. It is then secured to the suspension apparatus furnished by the repair ship.

REMOVAL OF ANGLE SOLVER CHASSIS FROM ITS CASE

19. Set the fwd Stop 10F to its zero end (driven end).

20. Remove the outer Depth Set Dial (four screws).

21. Remove the dial plate (six screws).

22. Remove the fwd Follow-up Motor 9F.

23. After the removal of this motor one of the two slip dowels will be seen, and a 10-24 screw must be inserted into the tapped hole visible in this dowel so that the dowel may be removed from the chassis.

24. The other dowel in the upper left hand corner behind the dial plate, not visible in Fig. 160, may be removed by grasping the cross bar inserted in its end, or by the above method using a 10-24 screw, whichever appears better.

25. Remove the aft Follow-up Motors 9A and 20A.

26. Remove the aft Stop 21A.

NOTE: It is also possible to remove the Angle Solver chassis from its case without removing the case from the bulkhead. If the Position Keeper had first been removed, push its cable back into the Position Keeper's case. Next remove the cable to the terminal blocks of the Angle Solver and keep it from resting on the Angle Solver by inserting a thin plate or the equivalent on top of the Angle Solver chassis. Each coupling must be individually turned so that when pushed towards the Position Keeper case, it will engage springs which will hold it disengaged from the Angle Solver. For the two back couplings a screwdriver must be used. Each of these couplings has a pin with a slot in it in which a screwdriver will fit. Now remove dowels and bolts and proceed as indicated.

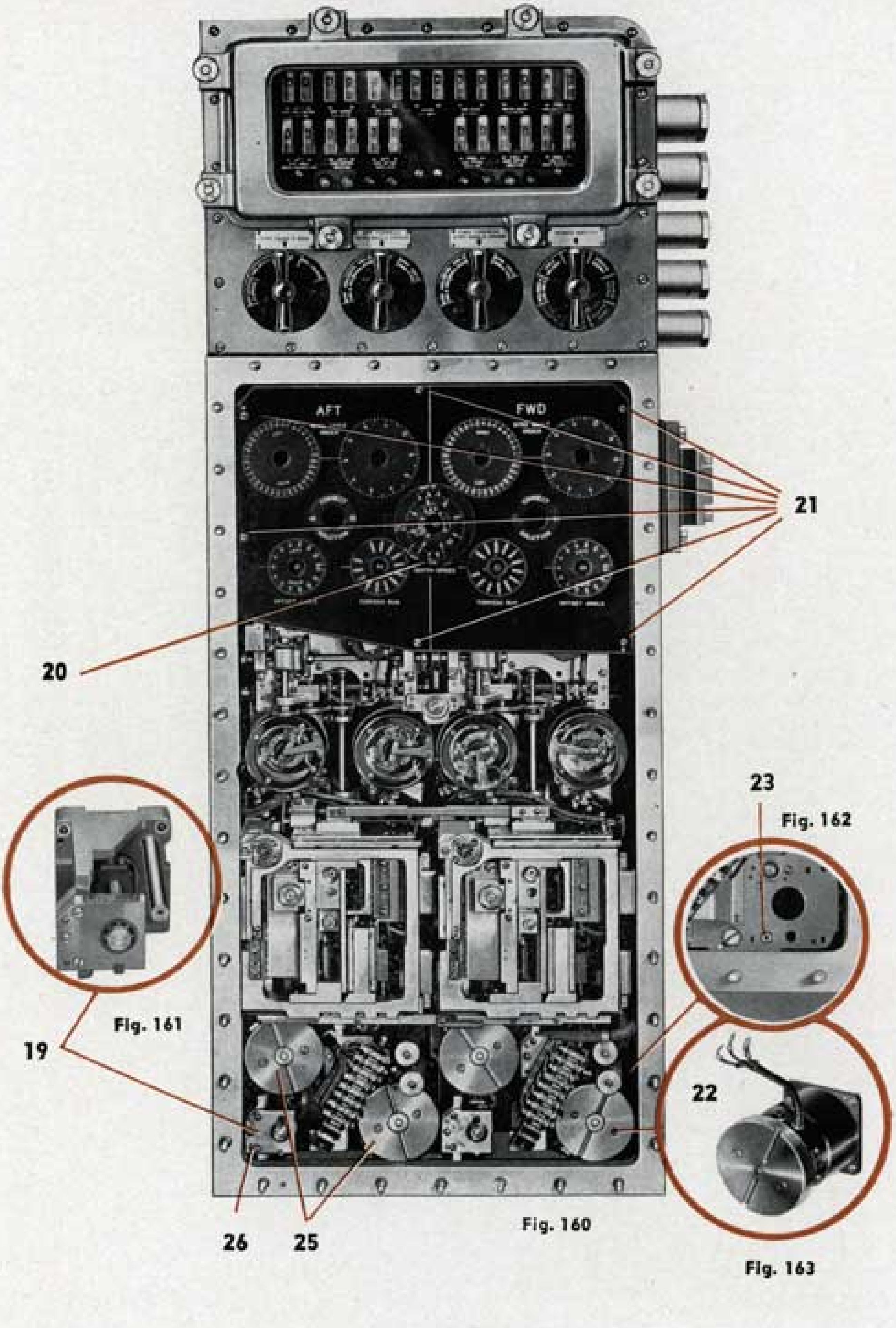


Fig. 162

Fig. 161

Fig. 160

Fig. 163

27. Remove the seven securing screws that fasten the chassis to the case. These screws are located around the outside perimeter of the chassis and are not visible in Fig. 164.

NOTE: In order to remove the Angle Solver when both cases are together it is also necessary to unmesh the six couplings which come into the case from the Position Keeper. This may be done by pushing each coupling to the left. The coupling will remain there provided that it occupies the correct angular position with respect to the two remaining fingers that keep it uncoupled. This position is varied as required by turning the proper hand crank.

28. Secure the plate to the bottom flange of the Angle Solver case and to the bottom of the chassis and insert sheet metal shield to protect wiring.

NOTE: It is possible to remove the chassis without the aid of screw jacks.

29. The chassis may now be carefully slid out onto the plate.

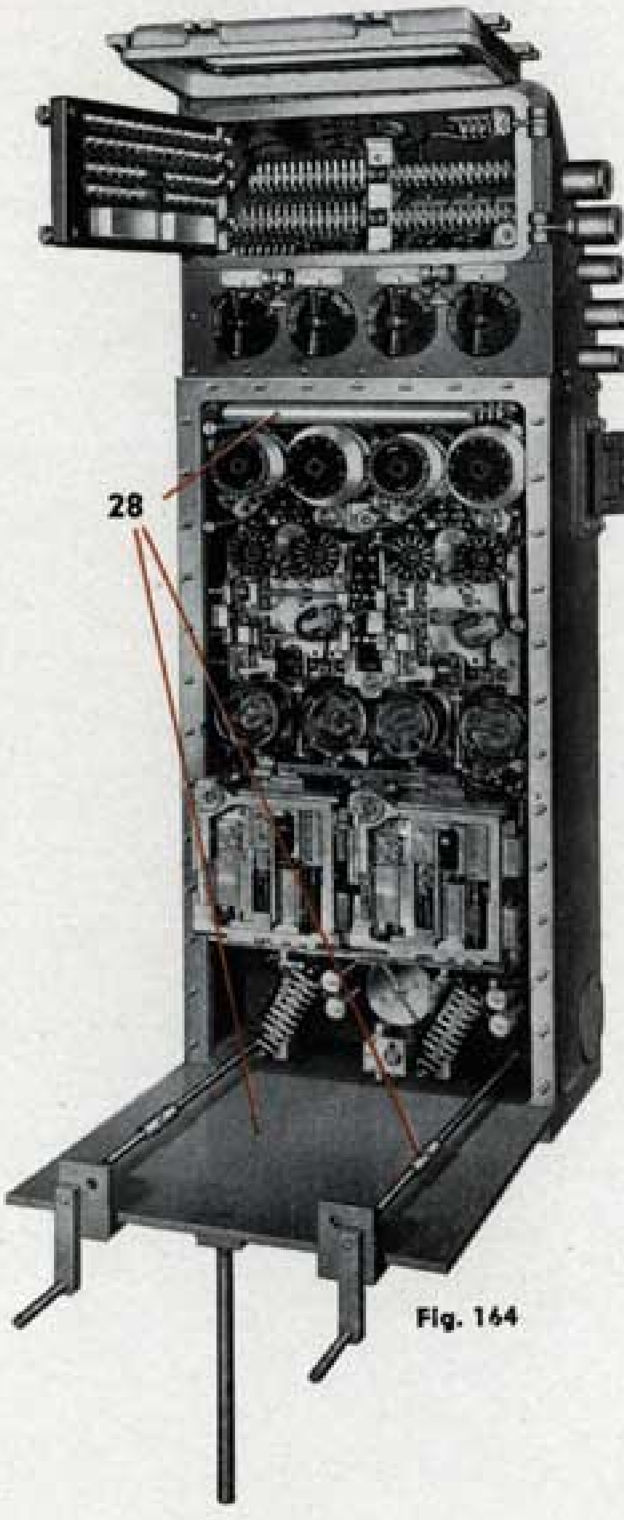


Fig. 164

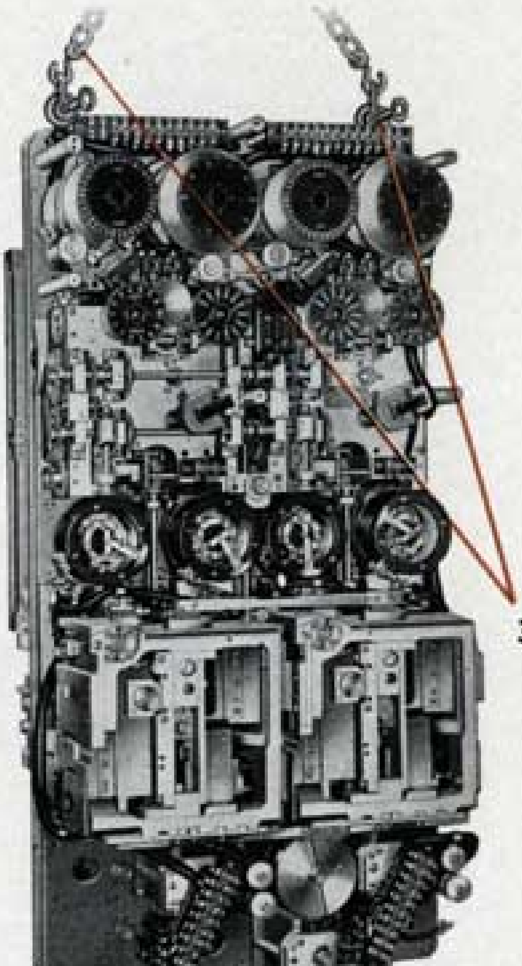


Fig. 165

30. The chassis should then be secured to the suspension apparatus.

DISASSEMBLY AND REASSEMBLY

DISASSEMBLY OF POSITION KEEPER CHASSIS

In disassembling the Position Keeper chassis it will be noted that the removal of the Sound Bearing Converter, Integrator Unit, Divider Unit, Time Motor Governor, Dial Unit, and any of the follow-up motors, follow-up heads, stops and synchro motors may be effected without necessitating the previous removal of some other unit.

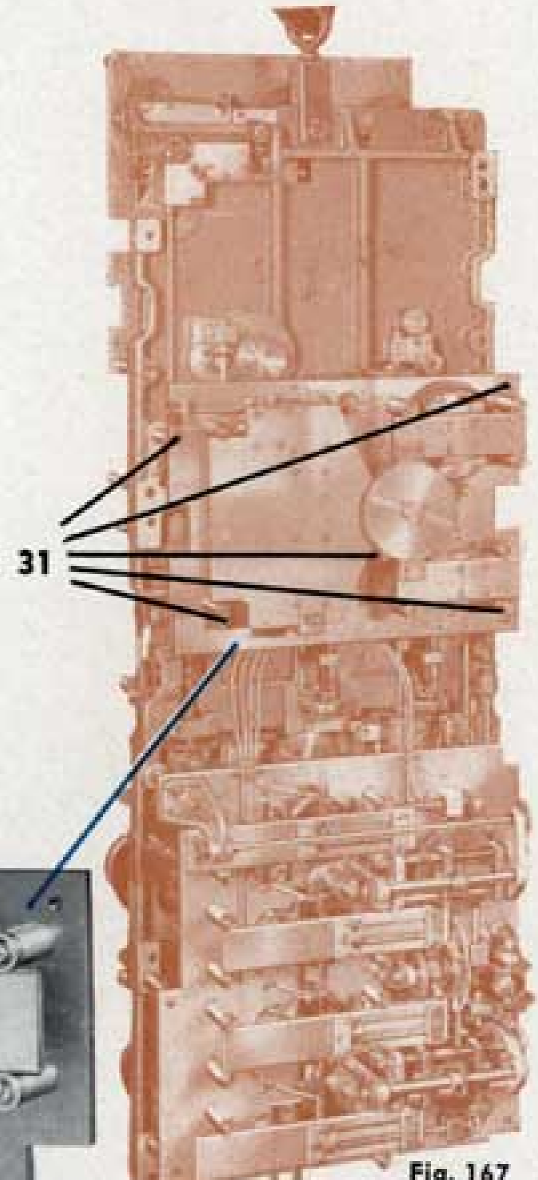


Fig. 167

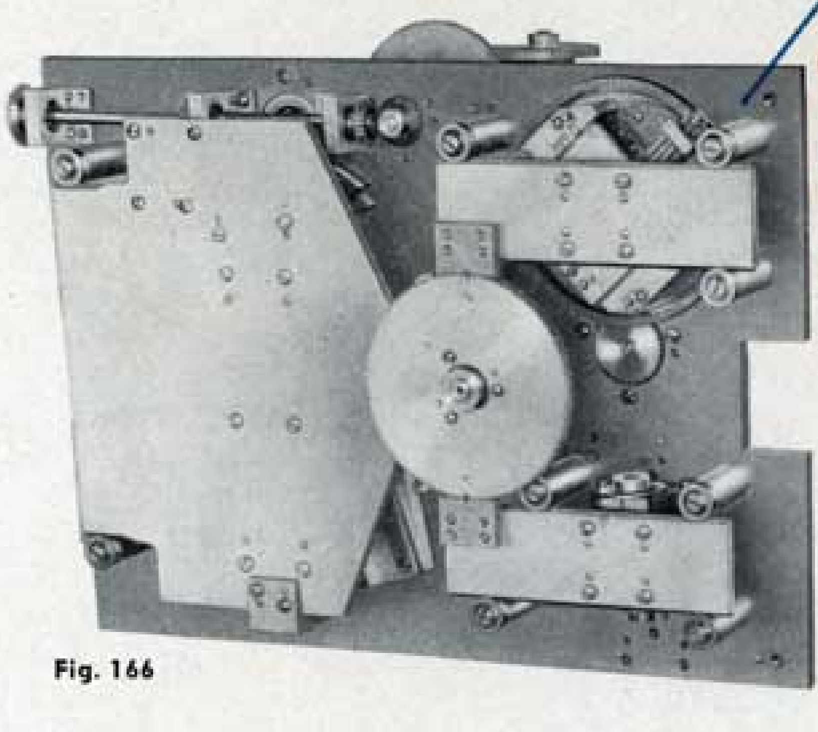


Fig. 166

31. By removing the five screws which secure it to the chassis, the Sound Bearing Converter may be removed as a unit. It will be noticed that six spur gear meshes become automatically unmeshed and particular attention must be paid to these meshes during the replacement of the unit.

32. In order to remove the Integrator Unit it is first necessary to disconnect the six oil pipes which may be accomplished by gently pulling the upper pipes out of their respective lower pipes.

33. Remove the six screws which secure the unit to the chassis and remove the unit.

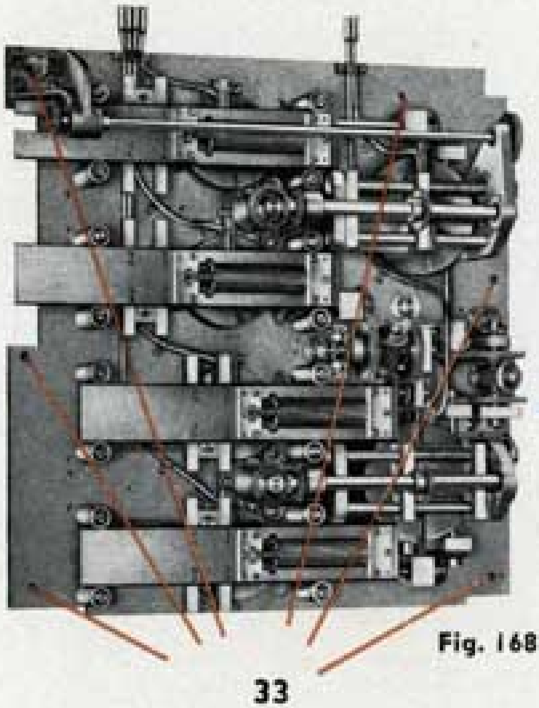


Fig. 168

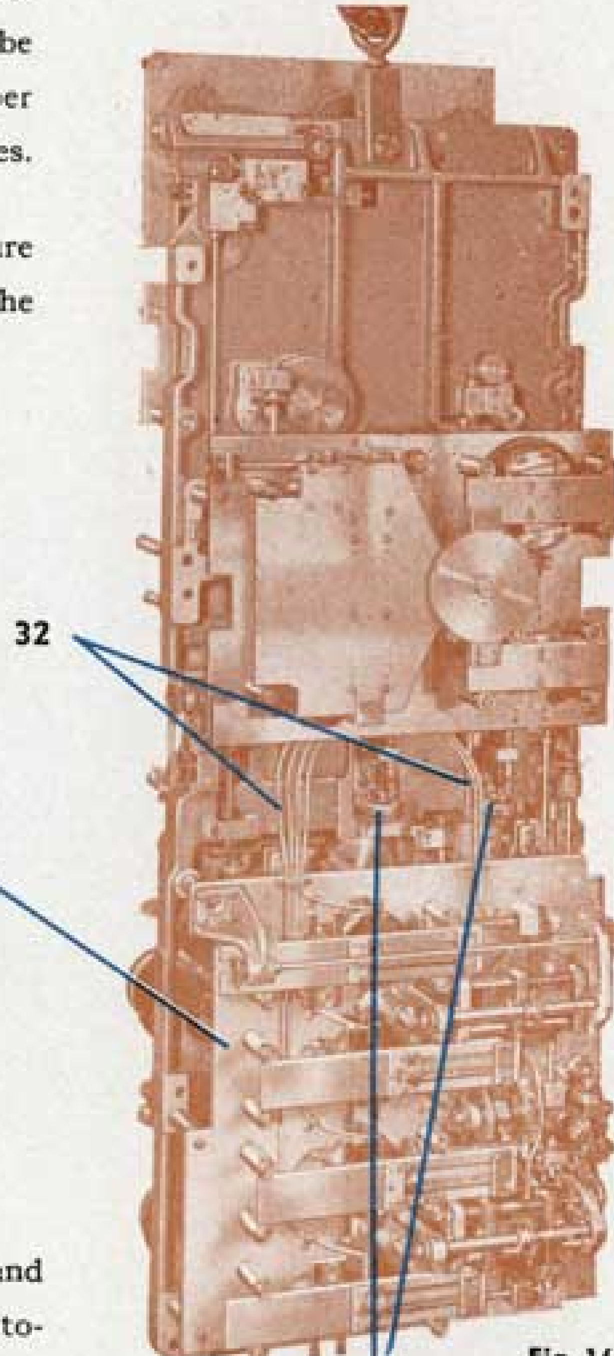


Fig. 169

It will be noticed that four spur gear and three bevel gear meshes become automatically unmeshed and particular attention must be paid to these meshes during the replacement of the unit.

34. The Range Stop and Target Length Stop on the back of the chassis may each be taken off by removing the four screws which secure the Stop in question.

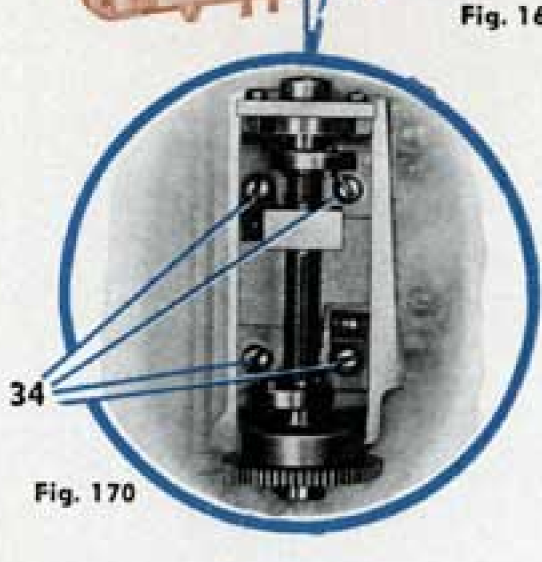


Fig. 170

DISASSEMBLY AND REASSEMBLY

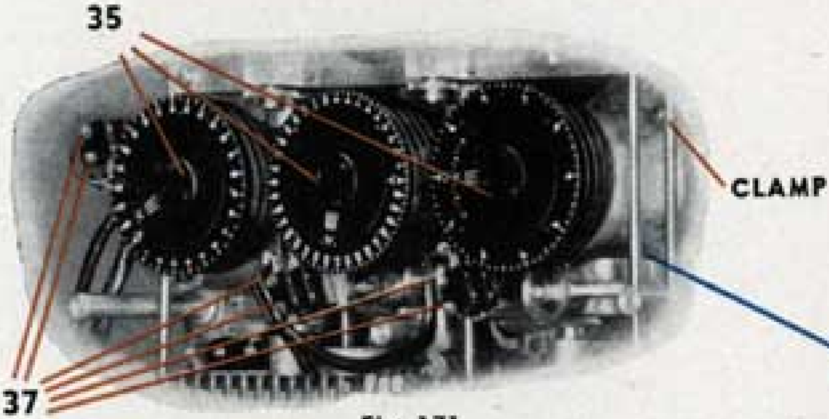


Fig. 171


Fig. 172

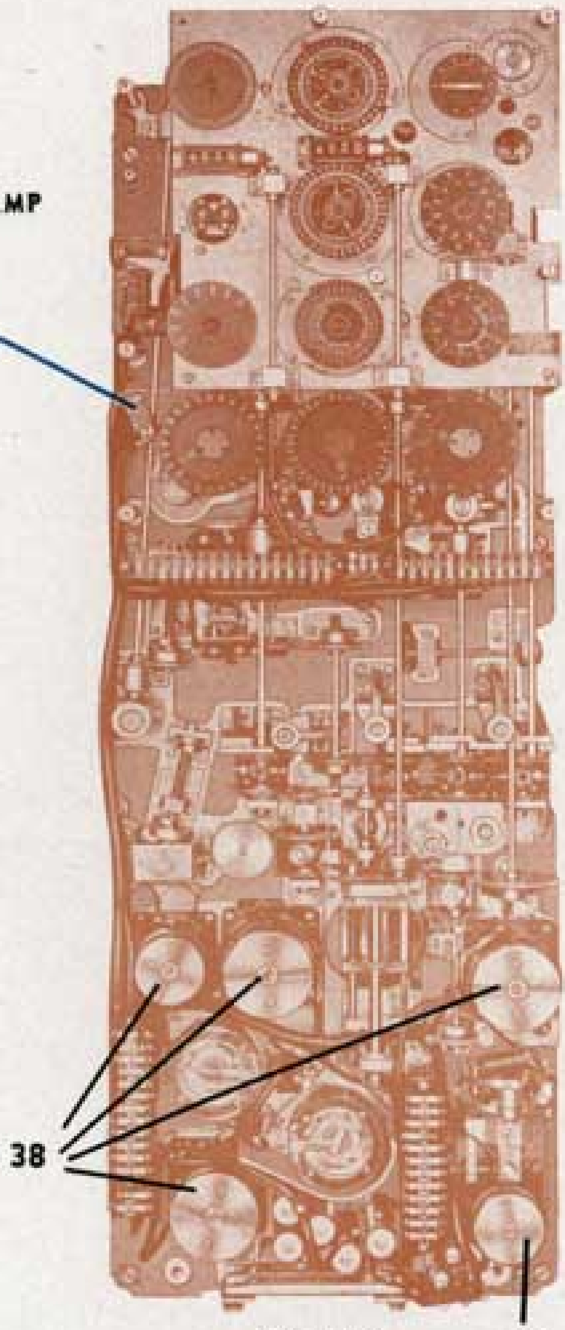


Fig. 173

35. Each of the three Synchro Motors (with their respective follow-up heads and dials) may be removed as follows: Remove the three securing clamps on each.

36. Disconnect the wiring and cable clips.

37. During the removal of a synchro, it will be necessary to hold the brushes, which contact its follow-up head, away from the collector rings. This may be easily accomplished by removing the two securing screws of the respective brush block.

38. Similarly, each of the four Follow-up Motors and the Time Motor may be taken off by removing the four securing screws and disconnecting the wiring of each motor.

Fig. 174

Fig. 176

39. Remove four securing screws, hold brushes aside to remove two Follow-up Heads.

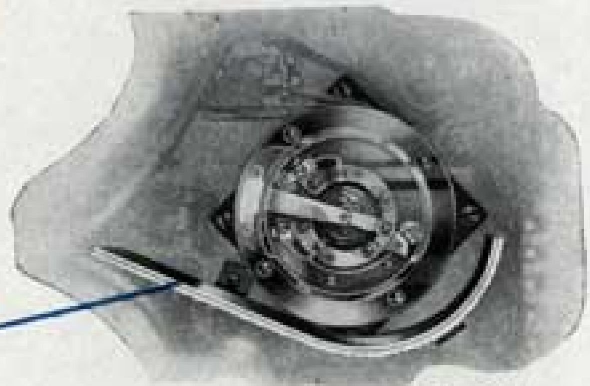


Fig. 177

40. To remove R△B Head, it is necessary to remove shield directly below it.

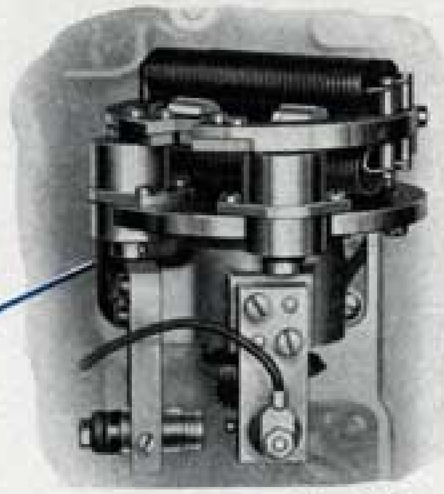


Fig. 178

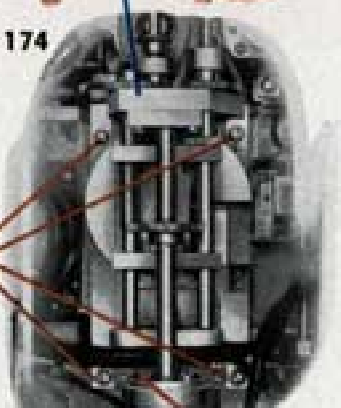


Fig. 175

41. The Time Motor Governor is removed by taking out its four securing screws and disconnecting the two leads.

42. Before removing Divider Unit, first remove the two screws and two slip dowels of the supporting bracket.

43. Disconnect right hand ends of the leads in the cable, which passes just above the lower bracket of the Divider Unit, so that cable may be pulled out of way.

44. Remove the four securing screws to disengage Divider Unit from chassis, being careful to unmesh gears on its upper bracket.

DISASSEMBLY AND REASSEMBLY

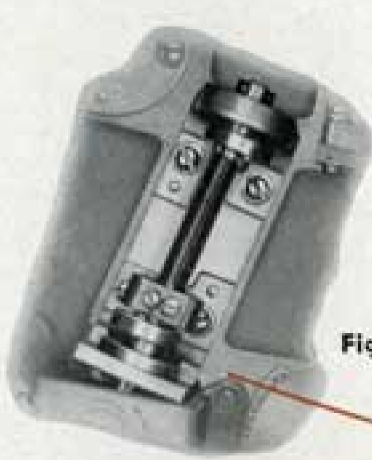


Fig. 180

45. The Own Speed Stop may be removed by taking out its four securing screws.

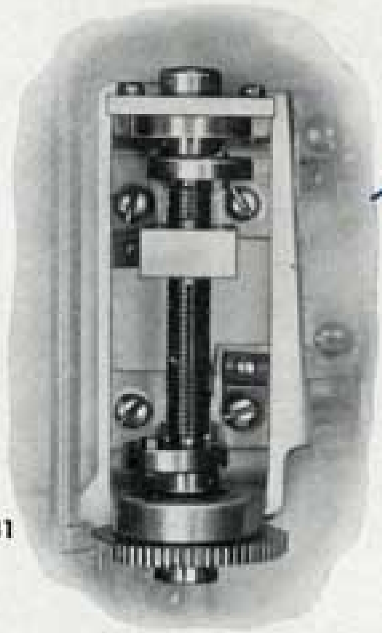


Fig. 181

46. The Target Speed Stop may be removed by taking out its four securing screws and two slip dowels.

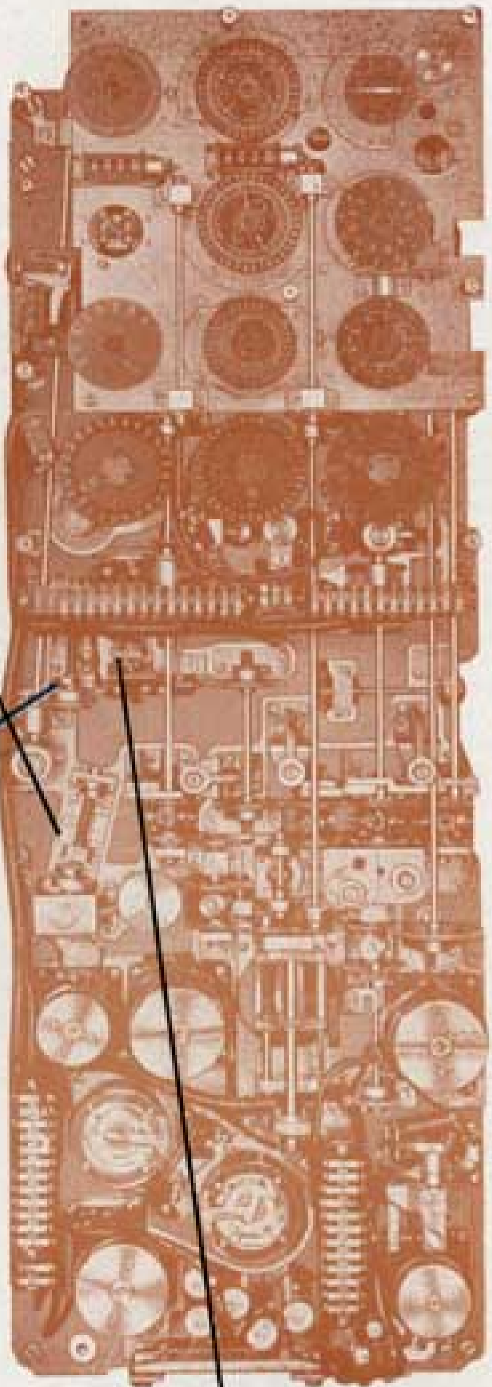


Fig. 179

47. The Angle Solver Range Stop may be removed after the two switches have been taken off. Each switch is fastened with two screws. The Stop is fastened with two slip dowels and four screws.

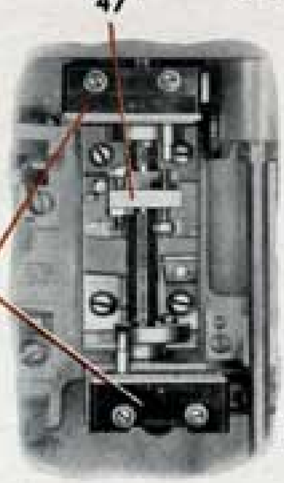


Fig. 182

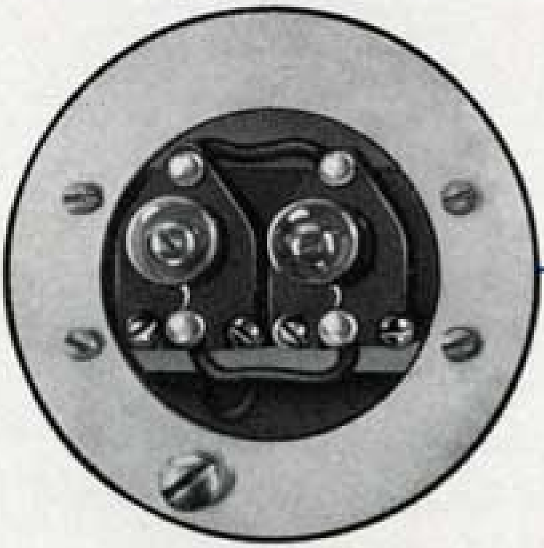
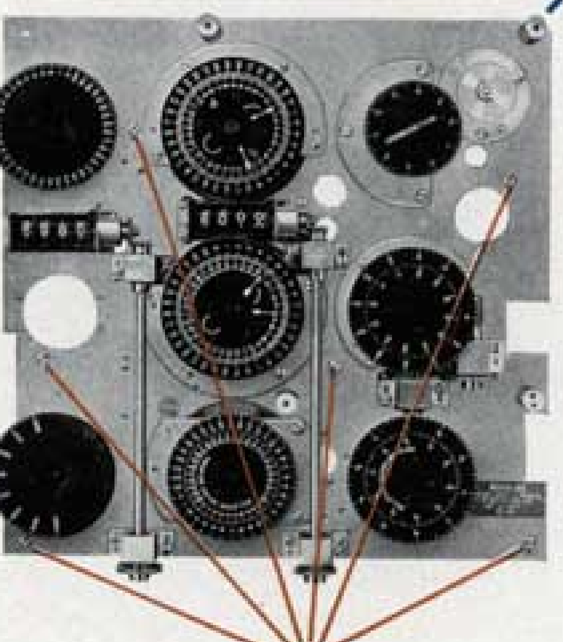


Fig. 183



48

Fig. 184

Fig. 185

48. In order to take off the Dial Unit it is necessary to remove the sockets of the generating lights from the rear of the unit. The subsequent removal of the six securing screws permits removal of the unit. The removal of the Dial Unit automatically unmeshes twelve gear meshes (six spur, three bevel, and three worm), and particular attention must be paid to these during the replacement of the unit.

The remaining gearing with its brackets, plates and shafting can now easily be removed as desired, and detailed information as to the exact procedure is considered unnecessary. It is essential, however, that the location of the parts be noticed so that reassembly can be accomplished without undue difficulty.

DISASSEMBLY OF ANGLE SOLVER CHASSIS

The procedure to be followed in disassembling the Angle Solver chassis is more dependent upon definite preliminary steps than is the disassembly of the Position Keeper Chassis. The following procedure *must be used.*

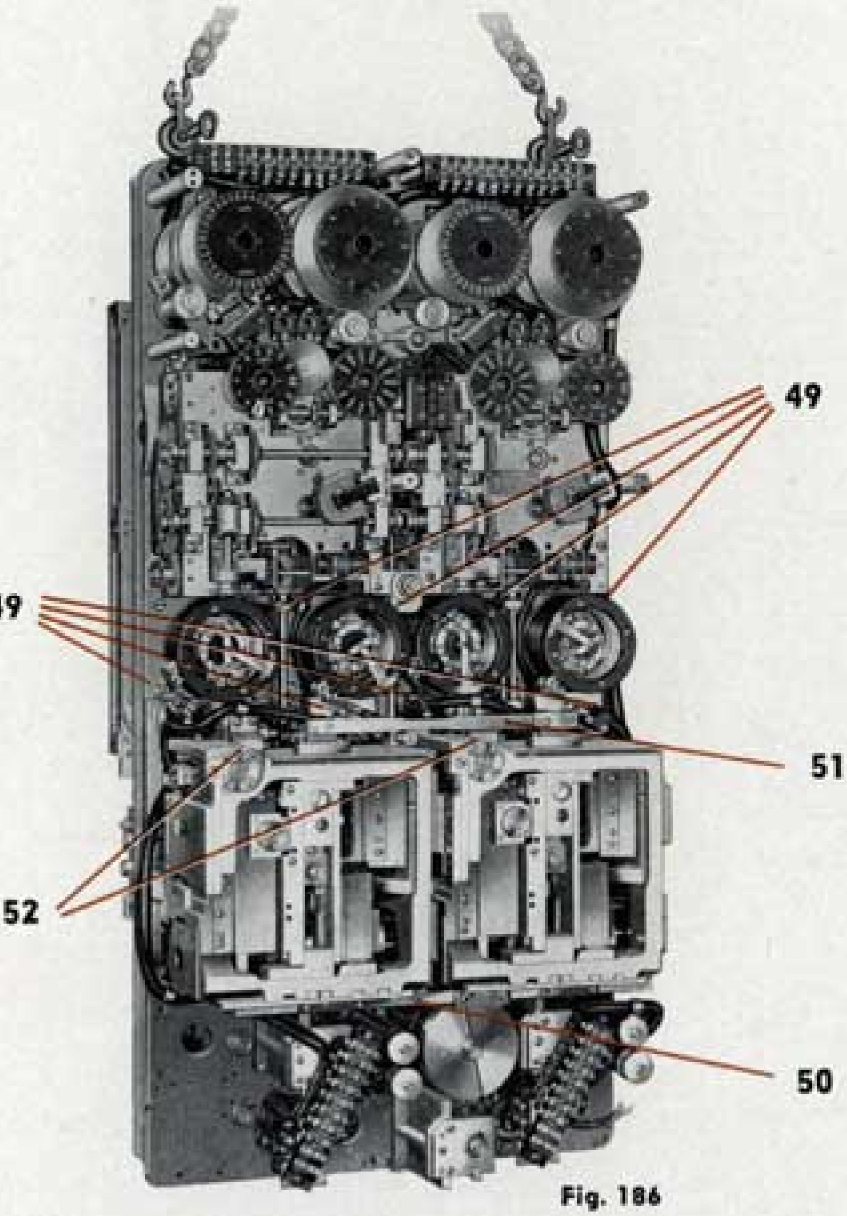


Fig. 186

49. Remove the four Follow-up Heads by removing the brush block of each and the four securing screws from the base of each.

50. Remove the connecting link of the Z carriages from the bottom of the two Cam Units (four screws).

51. Remove the connecting link of the M carriages from the top of the two Cam Units (two screws).

52. Remove the high speed Gyro Angle input gear and bracket from each Cam Unit (two slip dowels and two screws from each).

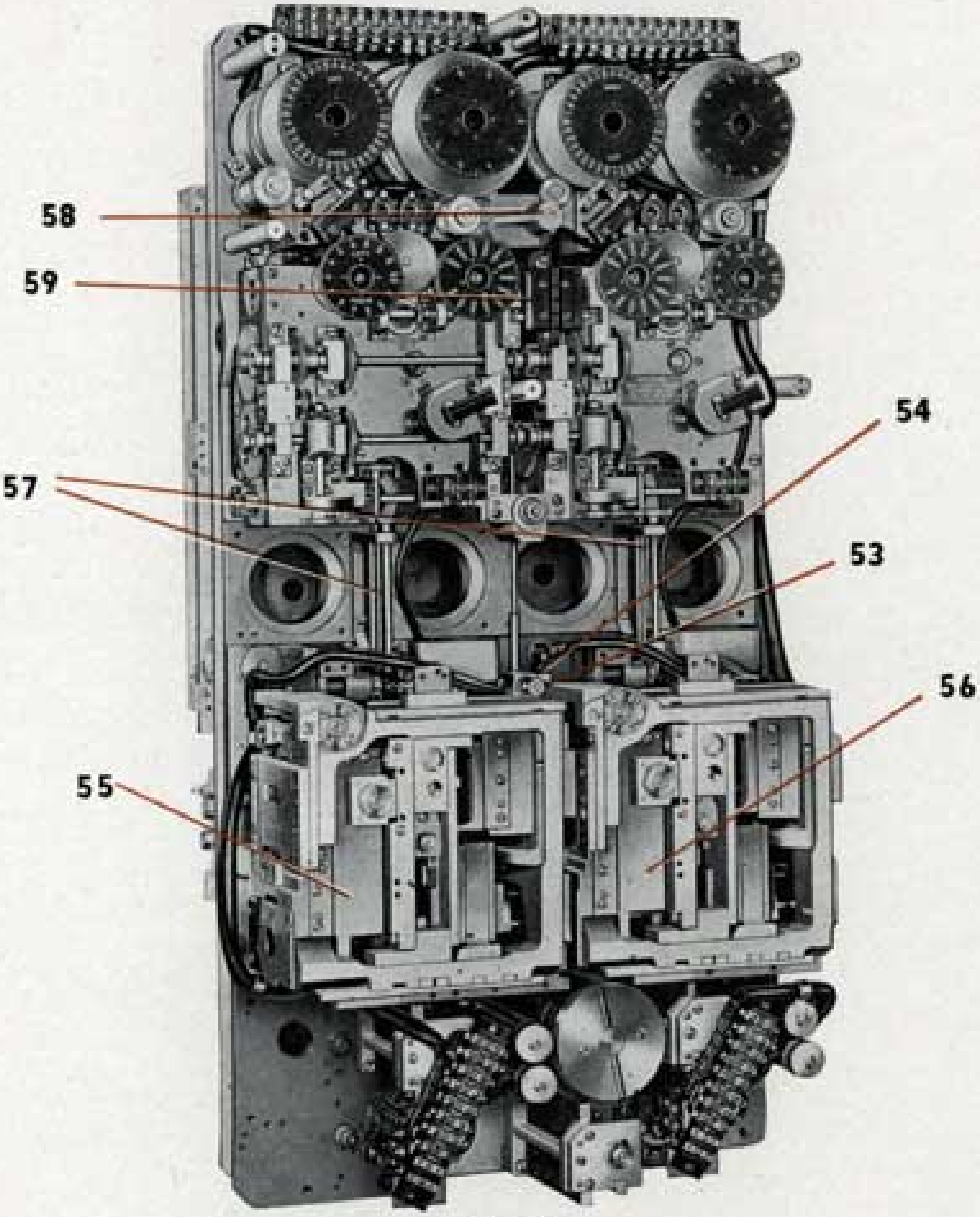


Fig. 187

53. Remove the gear from the front of the Uy input shaft located between the two Cam Units.

54. Remove the front bracket of the Uy shaft from the Cam Unit (two slip dowels and two screws).

55. Remove the six securing screws from the aft Cam Unit, and remove the unit from the chassis.

56. Remove the fwd Cam Unit (six screws).

57. Remove all the brackets, with their gearing, which are located below the two Differential Units.

58. Remove the Depth Set Dial mounting bracket (three screws).

59. Remove the Torpedo Run limit switch mounting bracket (three screws).

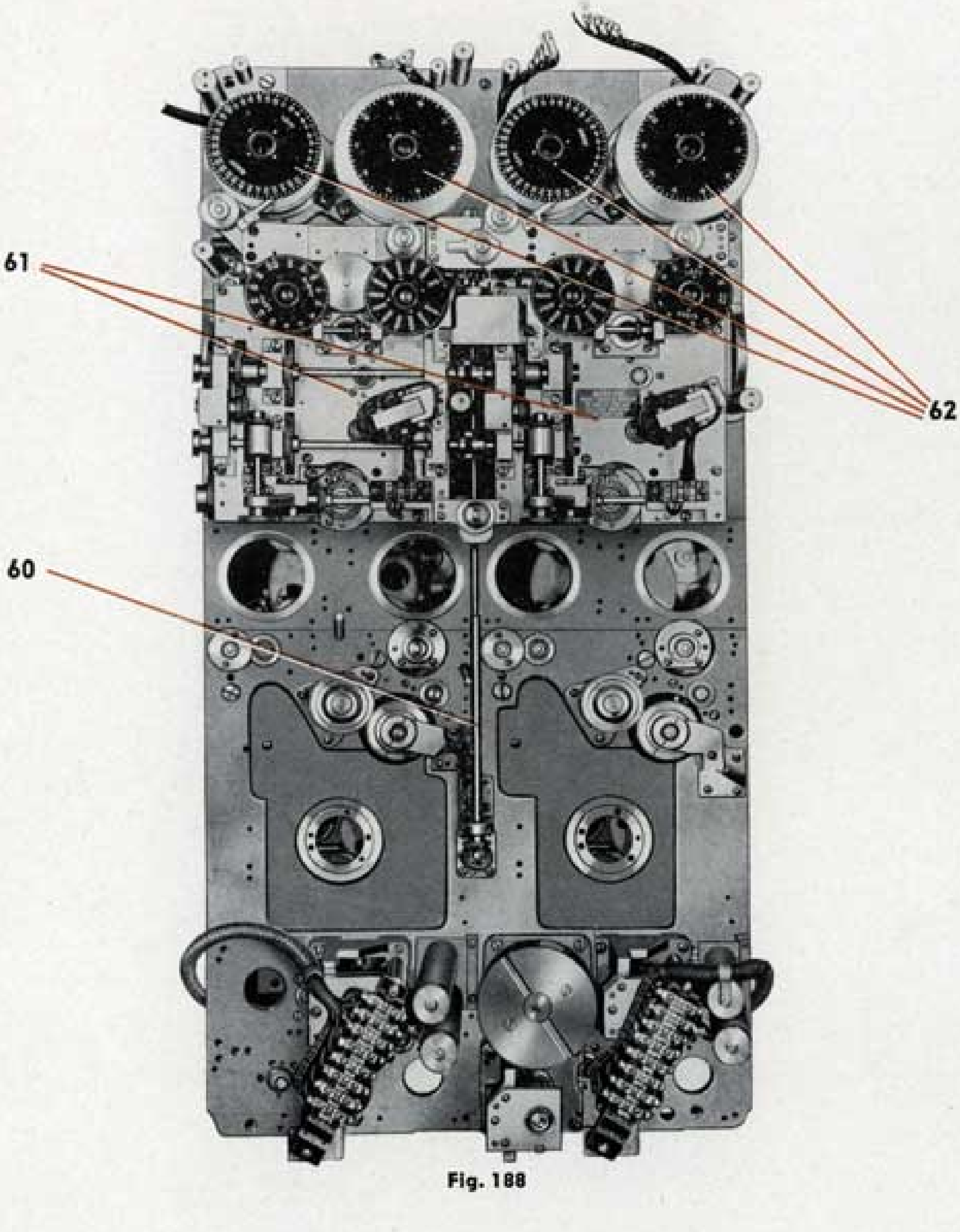


Fig. 188

60. Remove the long bronze shaft, with its three brackets and gearing, from the front center of the chassis.

61. Remove the Differential Units after taking out the four securing screws and disconnecting the wiring from each.

62. Remove the four Synchro Generators from the top of the chassis.

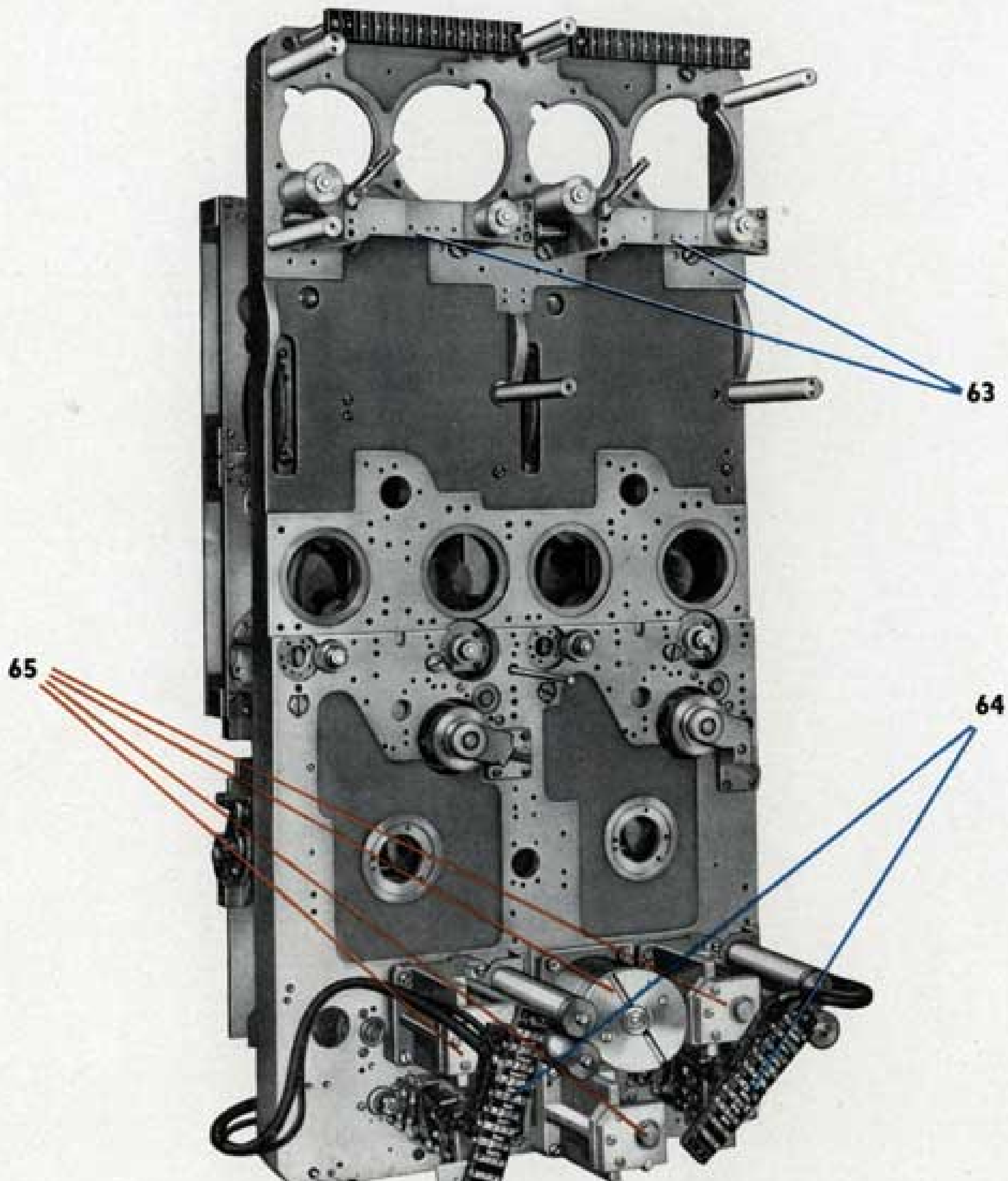


Fig. 189

63. Remove the brackets, beneath the four Synchros, which support the gearing which drives the Synchros.

64. Remove the two terminal blocks.

65. Remove the remaining Stops and follow-up motors from the bottom of the chassis.

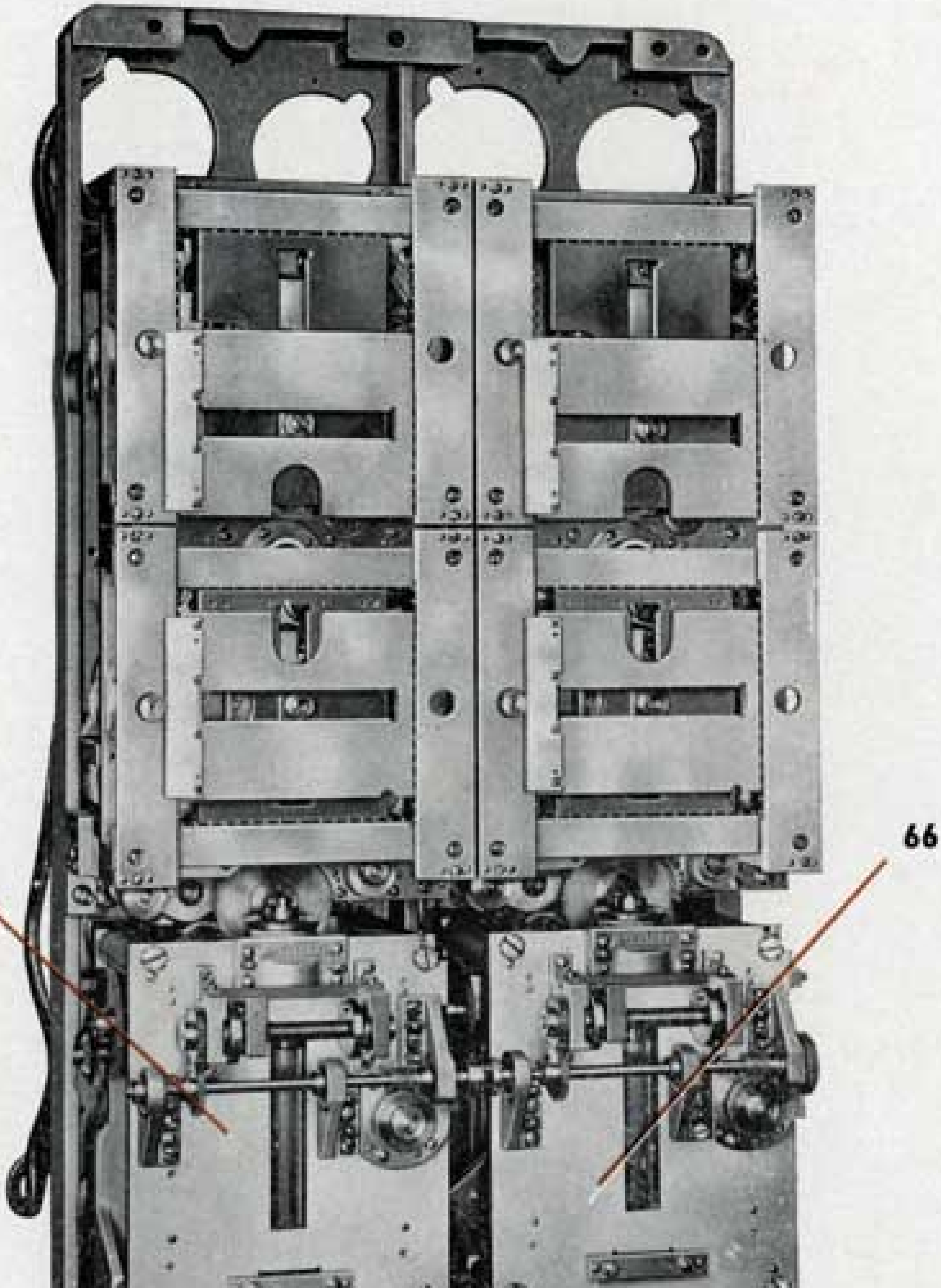


Fig. 190

66. Remove the aft Proportionator Unit after removing the two slip dowels and four hex-head bolts.

67. Remove the fwd Proportionator Unit (two slip dowels and four hex-head bolts).

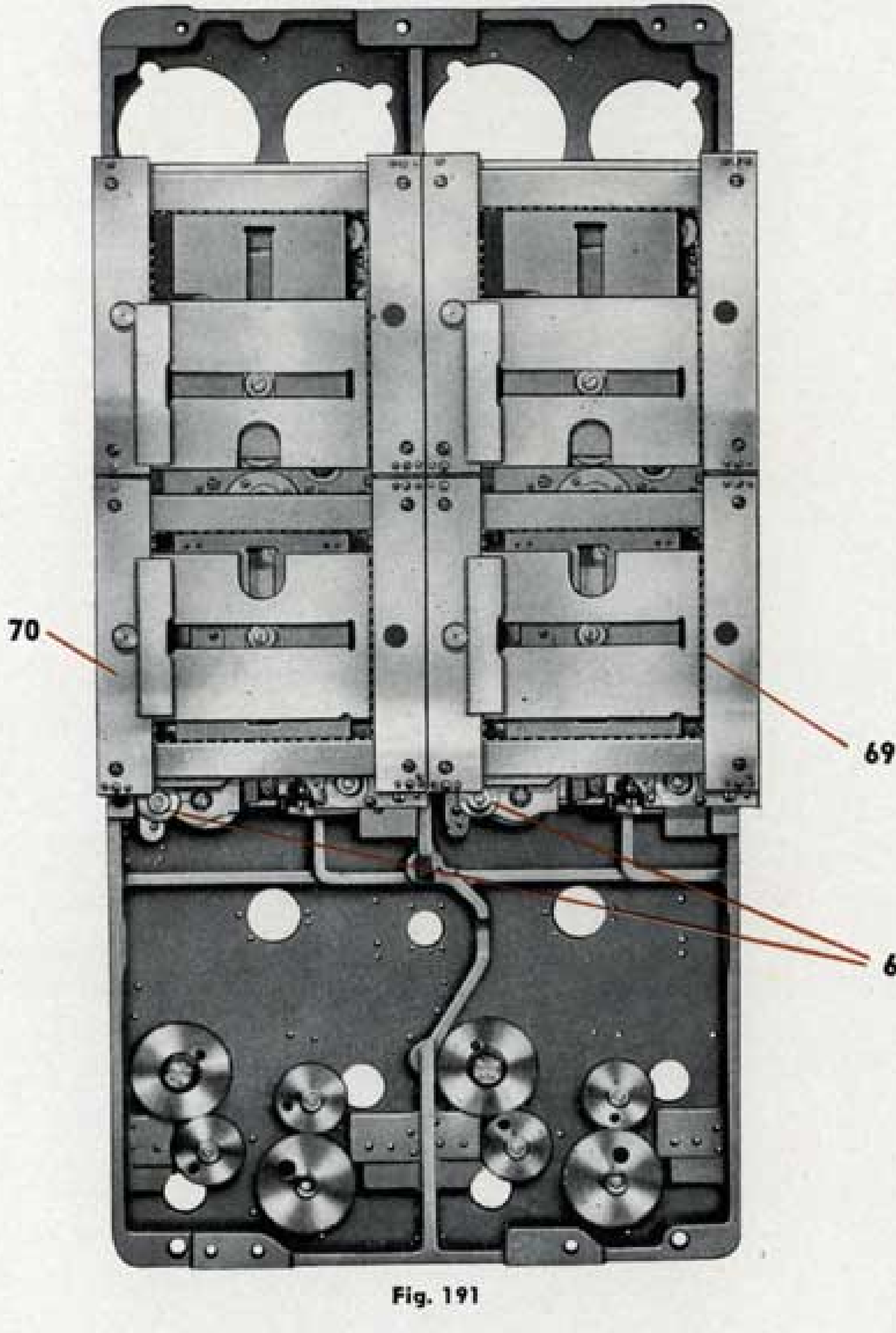


Fig. 191

68. Remove the connecting shaft with its gearing from the two Uy Stops which are indicated below the Resolver Units. (The shaft is not visible in this figure.)

69. Remove the aft Resolver Unit from the chassis (four hex-head bolts and one screw).

70. Remove the fwd Resolver Unit (four bolts and one screw).

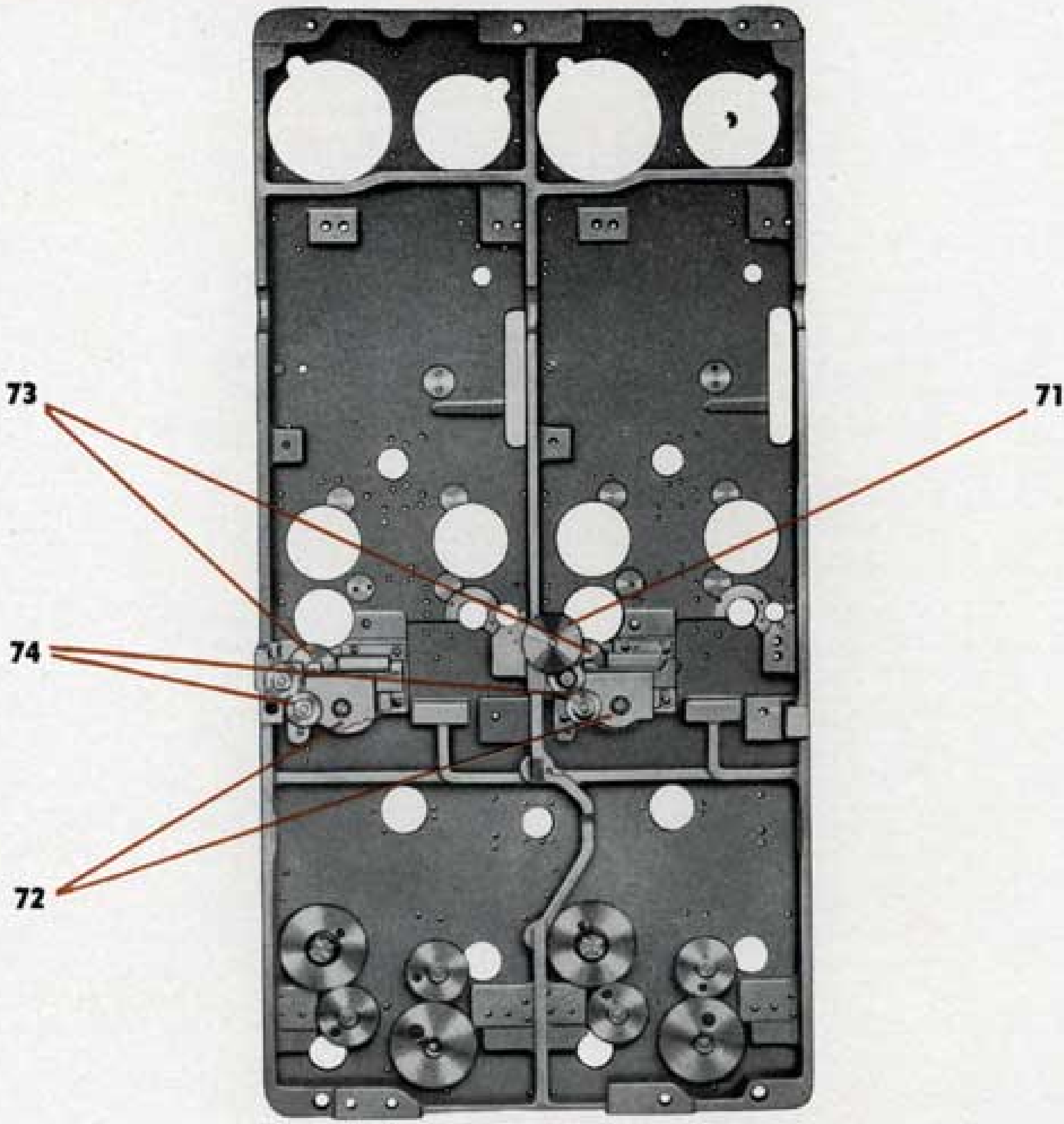


Fig. 192

71. Remove the four screws which secure the Uy bracket and shaft, and remove the bracket.

72. Remove both Uy Stop Units (three screws from each).

73. Remove each bracket, with its 56 tooth steel spur gear, from the chassis plate (two screws from each).

74. Remove each bracket, with its 37 tooth steel spur gear, from the chassis plate (four screws from each).

75. The remaining brackets with attached gearing, etc., can now easily be removed, if desired, and detailed information as to the exact procedure is considered unnecessary. It is essential, however, that the location of the parts be noticed so that reassembly can be accomplished without undue difficulty.

REASSEMBLY OF POSITION KEEPER CHASSIS

In reassembling the Position Keeper chassis, if it has been completely disassembled, it is first necessary to replace completely all of the gearing with its shafting, brackets, etc., which were referred to in the second paragraph of step No. 48 of the preceding section. It is then considered most expedient that the remaining units be replaced in the following order.

1. Carefully replace the Dial Unit, securing it by means of its six screws. There are twelve gear meshes which must be closely watched in order that none is incorrectly meshed and consequently burred or otherwise harmed. None of the meshes is synchronous, so that precaution in that direction is unnecessary. Final adjustment of the dials, pointers and counters will be described in subsequent steps.

2. Set the Range input of the Divider Unit on zero yards. This condition exists when turning of the $\triangle$B disc causes no motion of the R$\triangle$B roller.

3. Set the Range Counter (the center one) at zero yards. If the counter has been removed it will be necessary to readjust the positions of the gears on the drive shaft.

4. Replace the Divider Unit without disturbing the setting either on it or on the counter.

5. Secure the Divider Unit by means of its four screws.

6. Fasten the bracket which supports the lower end of the shaft leading to the Range Counter onto the upper bracket of the Divider Unit.

7. Set the Range Stop at its zero end (lower end) and replace it on the *back* of the chassis, thereby meshing it with the gearing of the Range Counter and the Divider Unit, which are still set at zero yards.

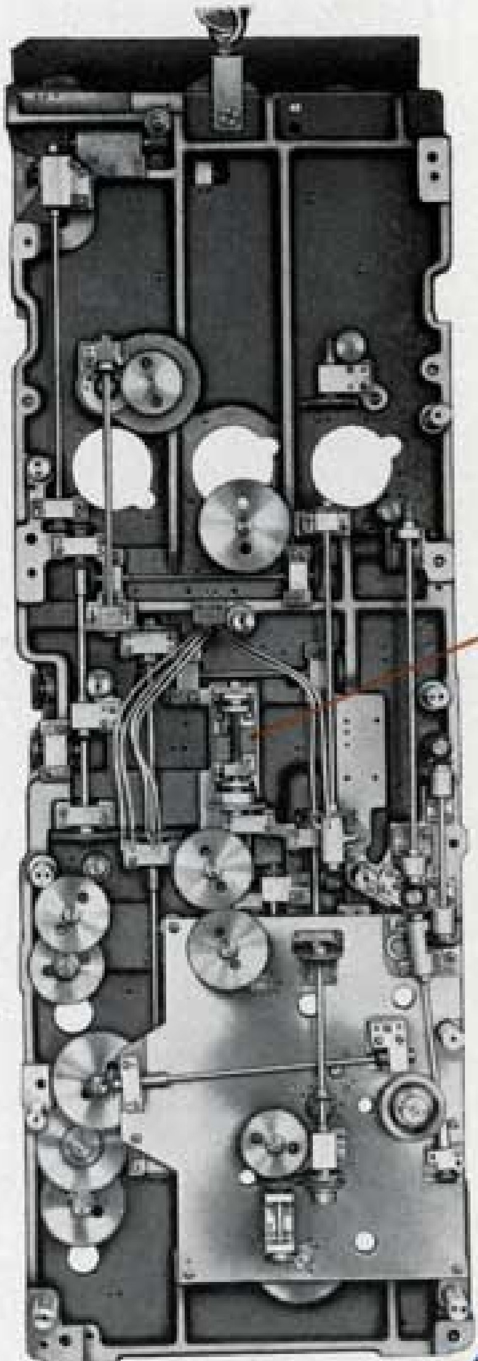


Fig. 193

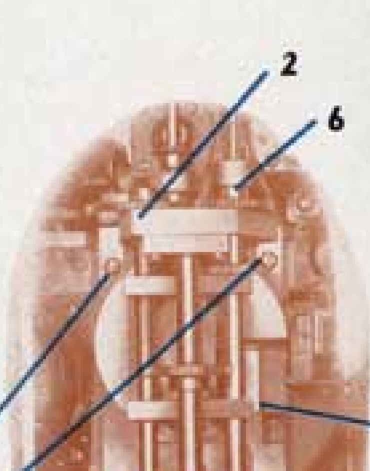


Fig. 194

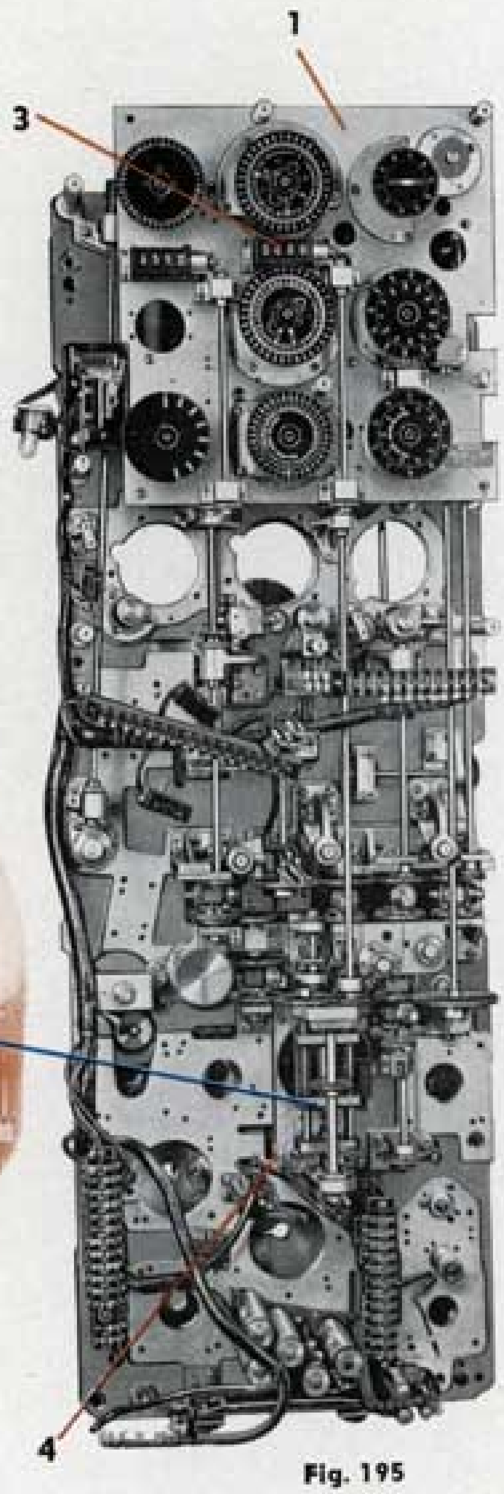


Fig. 195

8. Turn the 12 tooth steel spur gear which meshes with the Range input handle in the back of the front cover until the Range Counter reads 300 yards. It may be necessary to hold the upper gear of the Differential which is in this gear train and whose lower gear meshes with the Range input gear of the Divider Unit, in order to prevent the rotation from backing out through that Differential with the subsequent failure of the Range Counter and Divider Unit to go to 300 yards. It will be noticed that when the Range Counter is at 300 yards, the bronze Range input gear of the Divider Unit will have turned exactly 1½ turns.

9. Set the Angle Solver Range Counter to 300 yards. If the counter has been removed it will be necessary to readjust the positions of the gears on the drive shaft.

10. Replace the Angle Solver Range Stop, 44, with that Stop set at its 300 yard end (upper end) and secure it by means of the two slip dowels and four screws.

11. Replace the two switches on the Angle Solver Range Stop.

12. Set the Divider Unit, both Range Counters and both Range Stops to 300 yards.

13. Set the $\triangle$R Follow-up Head to the synchronized position. This position occurs when the two front rollers (high speed) are on the synchronized segment which is marked with a white "O", and at the same time the single roller (low speed), which contacts the same rings as the high speed rollers, is also on the zero island. This condition may be obtained by turning the gear on the back of the head which rotates the trolley assemblies.

14. Install the $\triangle$R Follow-up Head while it is in the synchronized position.

15. The R$\triangle$B Follow-up Head, the four Follow-up Motors and the Time Motor Governor and Time Motor may now be secured in place. As none of these units is synchronous, no special procedure need be employed.

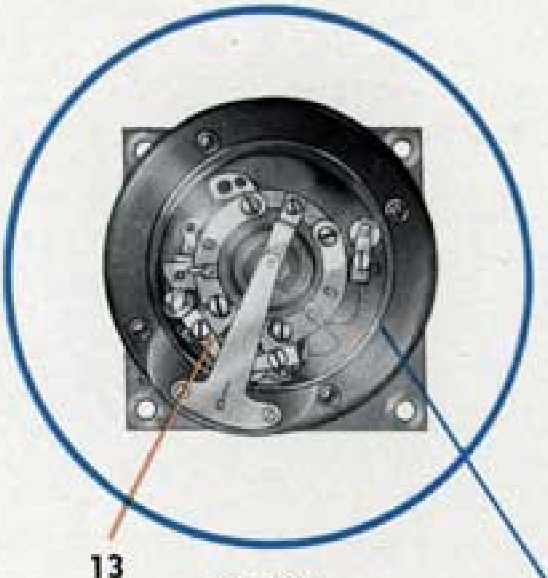


Fig. 197

Fig. 198

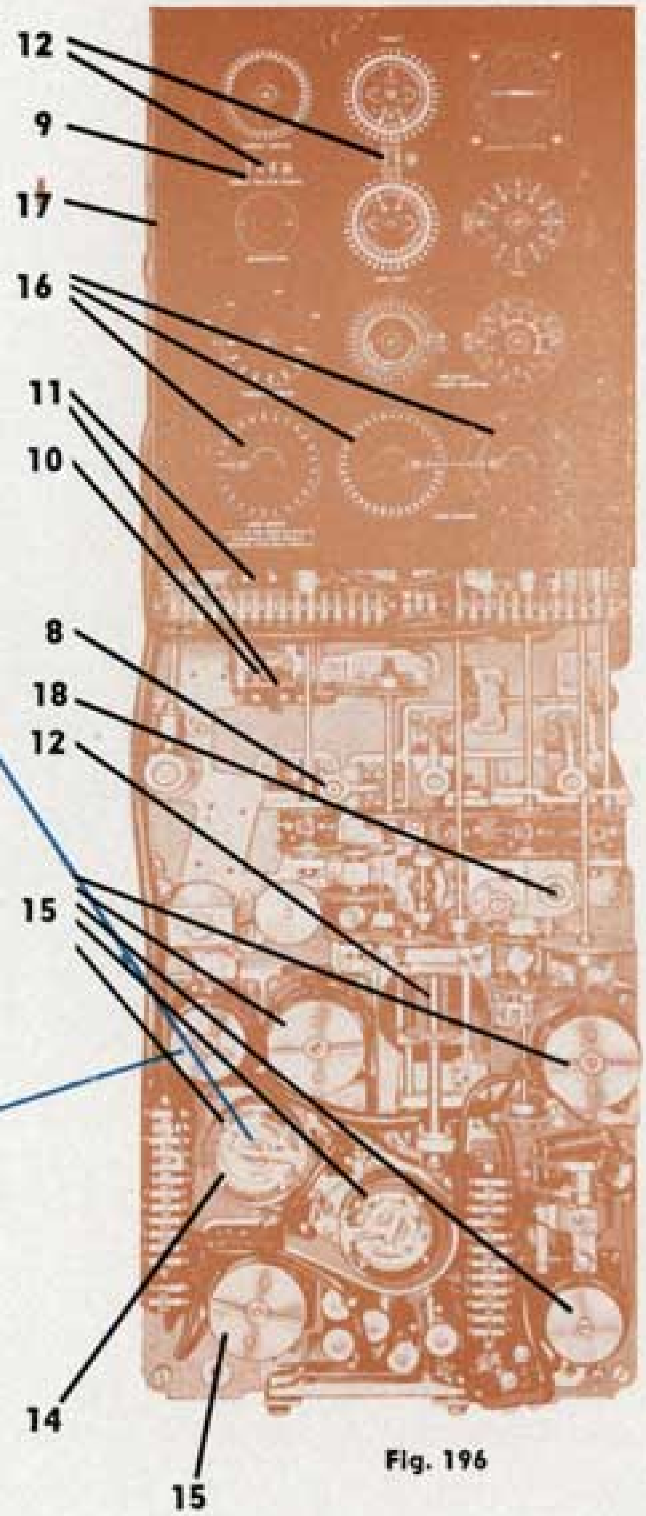


Fig. 196

16. Replace the three Synchro Motors with their respective Follow-up Heads and Dials.

17. Temporarily replace the index plate.

18. Turn the 12 tooth steel spur gear which meshes with the Own Course input handle in the back of the front cover, until any numbered graduation on the 1-speed Own Course Dial is aligned with the Own Course index line.

19. Remove the index plate.

20. Unmesh the 36-speed Own Course Head from its gearing by removing the Synchro Motor.

21. Turn the head on this motor until the zero graduation on the dial is aligned with the numbered graduation on the 1-speed Dial.

22. Replace the motor. This remeshes the gearing of the head.

23. Replace the index plate. It will be noticed that both the zero graduation of the 36-speed Dial and the numbered graduation of the 1-speed Dial are aligned with the index line.

24. Crank the Own Course input gear until the two dials read zero degrees Own Course.

25. Carefully replace the Integrator Unit, securing it by means of its six screws and reconnect the six oil pipes. As stated previously, there are seven gear meshes which must be closely watched in order that none is incorrectly meshed and consequently burred or otherwise harmed.

26. Turn the Target Speed input gearing of the Integrator Unit until the roller is so positioned on its disc that turning of the disc (by turning the Time Motor) causes no motion of the roller. This is the zero knot position of Target Speed.

27. Set the Target Speed Stop at its zero end (upper end).

28. Secure the Target Speed Stop to the front of the chassis.

29. Set the Target Speed Dial to read zero with the aid of a synchro dial wrench.

30. Turn the Own Speed input gearing of the Integrator Unit until the roller is so positioned on its disc that turning of the disc (by turning the Time Motor) causes no motion of the roller. This is the zero knot position of Own Speed.

31. Turn the bevel gear which meshes with the bevel gear on the threaded shaft and positions the Own Speed roller. This steel bevel gear must be turned 80 revolutions in a clockwise direction looking from the rear of the unit, and upon so doing, the Own Speed input will be at the maximum setting. When the instrument has a 25 knot integrator and a 22 knot dial, turn the integrator shaft 16 turns from the zero position where the lines on the gear line up. Then set the dial at the 5 knot position. In order to set the dial to the correct graduation, it may be necessary to remove the screws from the bracket and break the bevel gear mesh.

32. Set the Own Speed Stop at its maximum end (lower end) and secure it to the front of the chassis.

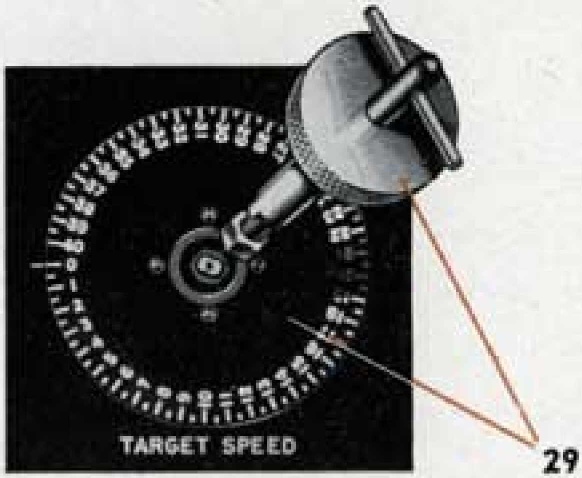


Fig. 201

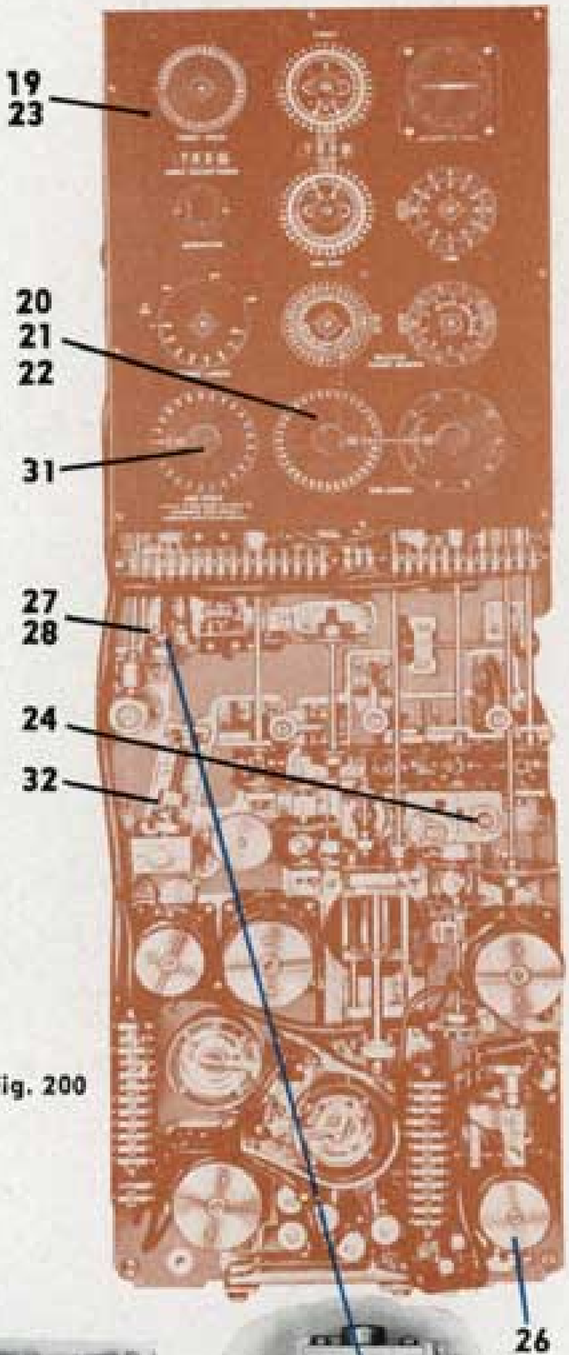


Fig. 200

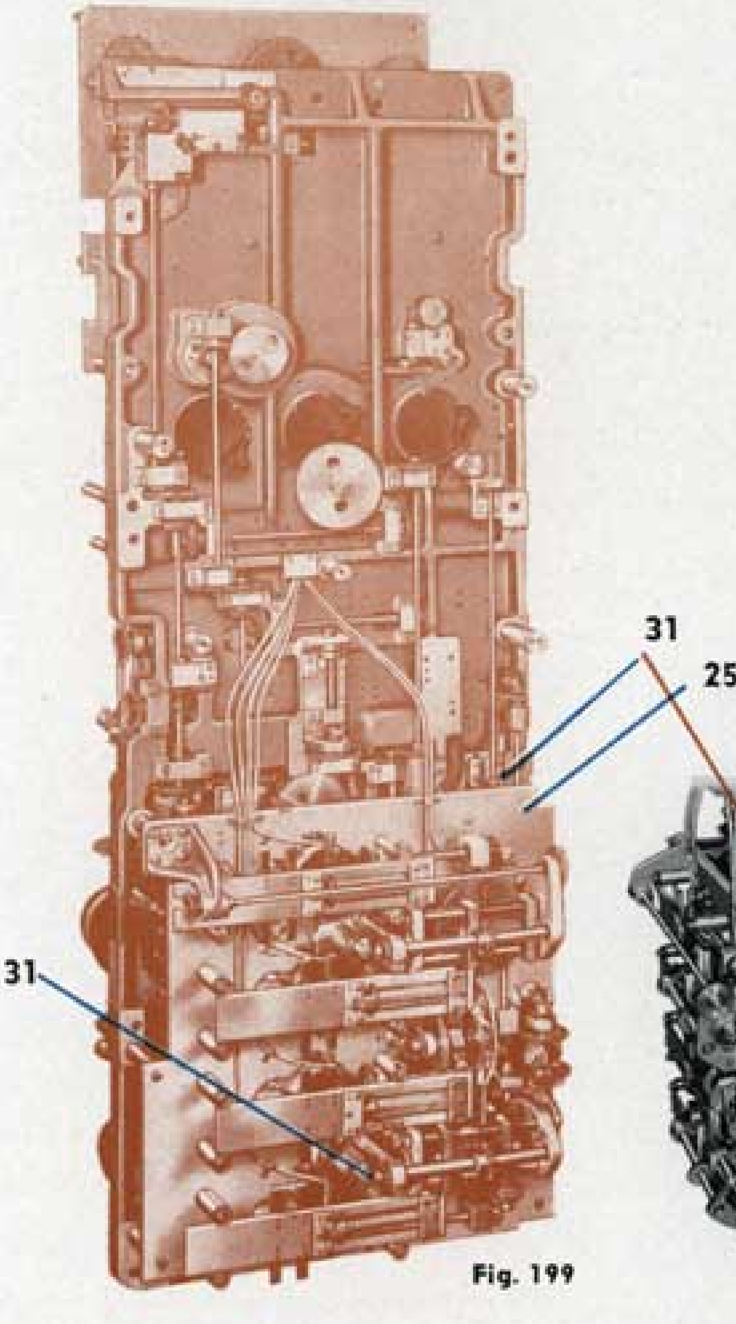


Fig. 199

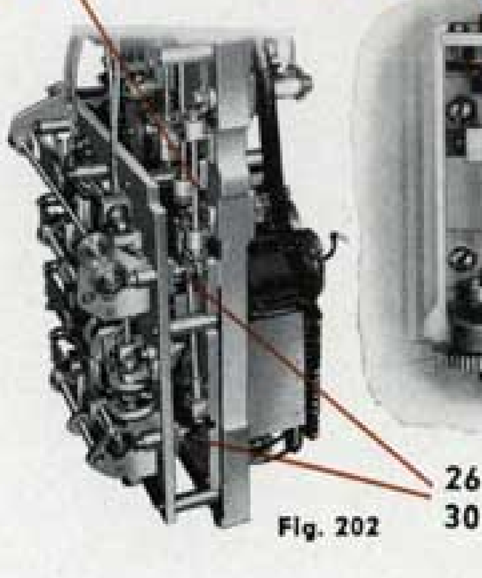


Fig. 202

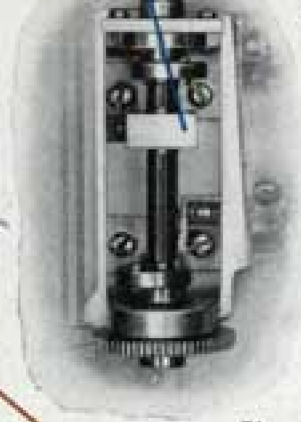


Fig. 203

33. Remove the index plate.

34. Remove the Own Speed Synchro Motor until the follow-up gearing is unmeshed.

35. On the Mods. 6, 7, and 12 instruments, turn the head and dial until the 22 knot graduation is positioned so that it will be aligned with the index line on the index plate upon replacement of the plate. On the other Mods. turn the head and dial until the 25 knot (zero) graduation is similarly positioned.

36. Secure the Synchro with the dial in this position.

37. Replace the index plate and check the dial setting, removing and resetting if necessary.

38. Turn the 12 tooth steel spur gear (which meshes with the Target Bearing input handle in the back of the front cover) until the bronze arm on the back of the Integrator Unit which positions the sin Br carriage is pointed directly upwards.

39. With the Own Speed input still set in its maximum position, turn the Time Motor which will turn the $\int S_o dT$ discs. When the roller on the sin Br carriage does not move during turning of its disc, the Relative Target Bearing dials can be set on zero degrees which is accomplished by loosening the four small screws in each ring dial, shifting the dial and tightening the screws.

40. Turn the 12 tooth steel spur gear, which meshes with the Target Course input handle in the back of the front cover until the bronze arm on the back of the Integrator Unit, which positions the sin A carriage, is pointed directly downwards.

41. Set the Target Speed to 40 knots.

42. Turn the Time Motor which will turn the $\int S dT$ discs. When the roller on the sin A carriage does not move during turning of its disc, and provided the Own Course and Relative Target Bearing Dials are still set at zero degrees, the Target Course Dials can be set at 180 degrees. The low speed ring dial is set by loosening the four small screws, shifting the dial and tightening the screws; while the high speed inner dial is set with the aid of a synchro wrench. On instruments containing a Distance to Track Indicator the outer ring dial is a high speed dial and the low speed dial will be eliminated. In this case, use Step 44 instead of Step 42.

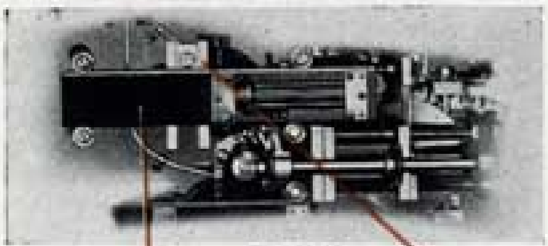


Fig. 205

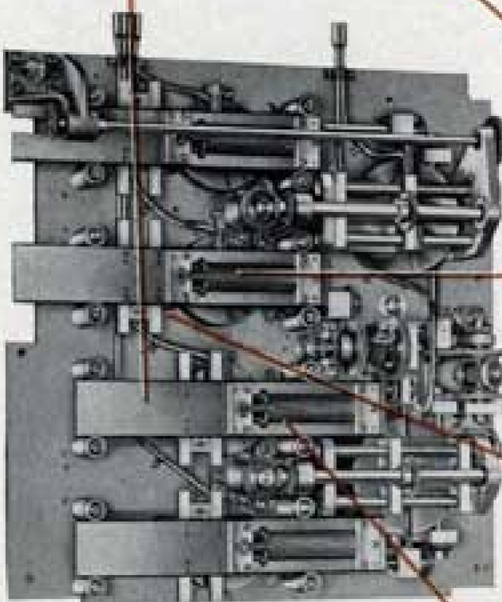


Fig. 206

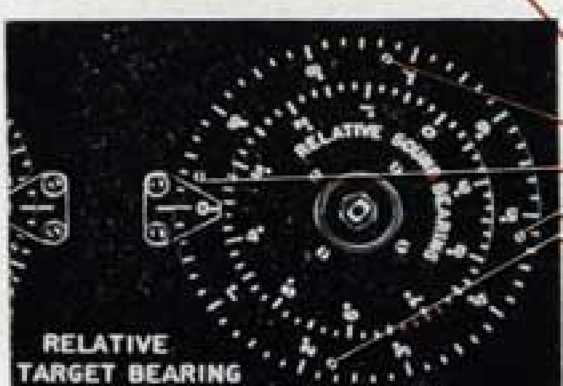


Fig. 207

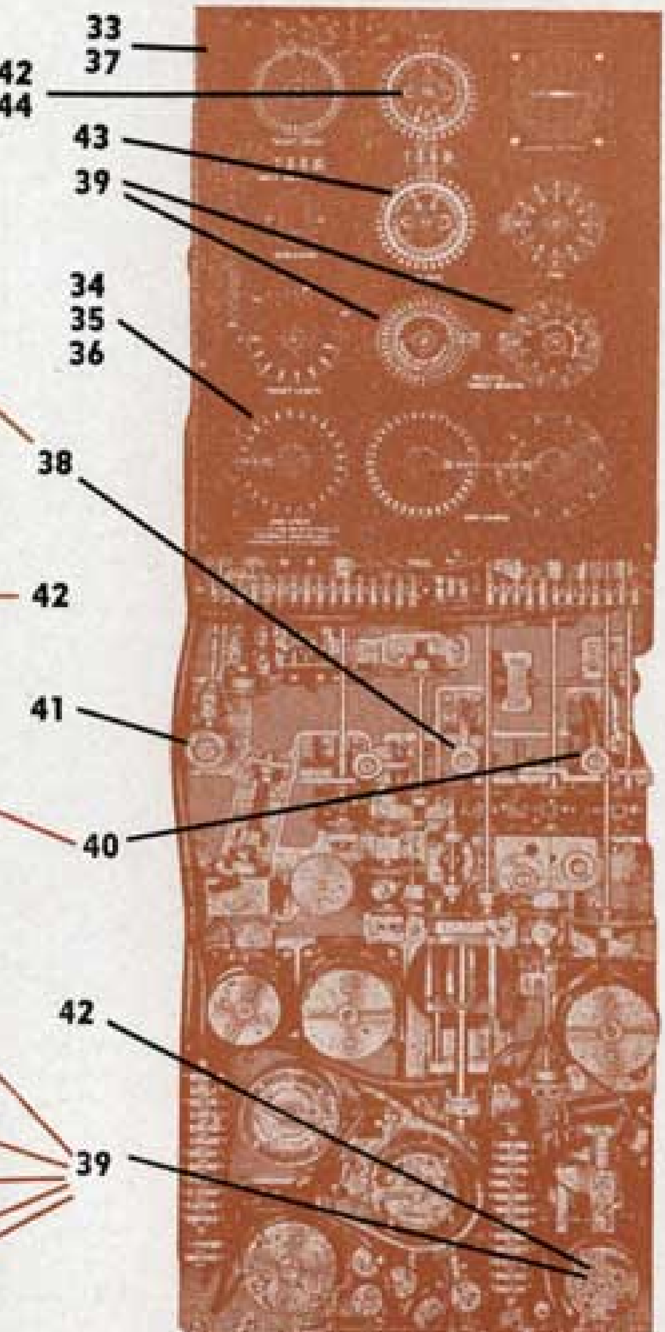


Fig. 204

43. Set both Own Ship Dials to read zero degrees against their index marks (ship on the inner dial pointing upwards). This is done by loosening the four small screws in each dial, shifting the dial and tightening the screws.

44. Set both Target Dials, the inner one to zero (ship pointing downwards), and the ring dial to 180 degrees. This is done in a manner similar to that used on the Own Ship Dials as described in Step 43.

The following steps are for setting the SOUND BEARING CONVERTER. This is best accomplished on a bench.

45. CAUTION: The large differential gear which connects the P1 Resolver and the P2 Resolver to the Range Resolver must be temporarily removed as a safety check. An attempt to bring Range down to zero when Target Angle or Relative Target Bearing are at values other than zero degrees would strain and possibly seriously damage the followers and rails of the Resolvers. Similarly, if any output is created from either the P1 or the P2 Resolver when Range is at zero, damage will result.

46. Turn the Br input gearing until motion of the P1 traveling nut from one extreme to the other causes no motion on the P1 sin Br carriage as measured by a dial indicator, and at the same time the indicating dial on the P1 shaft is at the bottom of the Resolver. This is the zero position of the Br input and the gears should be properly marked in case the existing marks do not line up. This could be the case if the unit had been completely disassembled and the gears were not remeshed as originally.

47. Set the P1 Dial to the correct position to agree with the Sound Base Line of the ship (refer to the section on Adjustments).

48. Turn the A input gearing until motion of the P2+3SR/2889 traveling nut from one extreme to the other causes no motion on the P2+3SR/2889 sin A carriage as measured by a dial indicator, and at the same time the small pinion gear which runs around the edge of the crown gear is at the bottom of the Resolver. This is the zero position of the A input and the gears should be properly marked in case the existing marks do not line up.

49. Run the traveling nut back toward the center of the Resolver (toward the 150 foot position).

50. Take a reading on the dial indicator, and then turn the worm shaft which drives the A input, exactly 18 revolutions in either direction from zero.

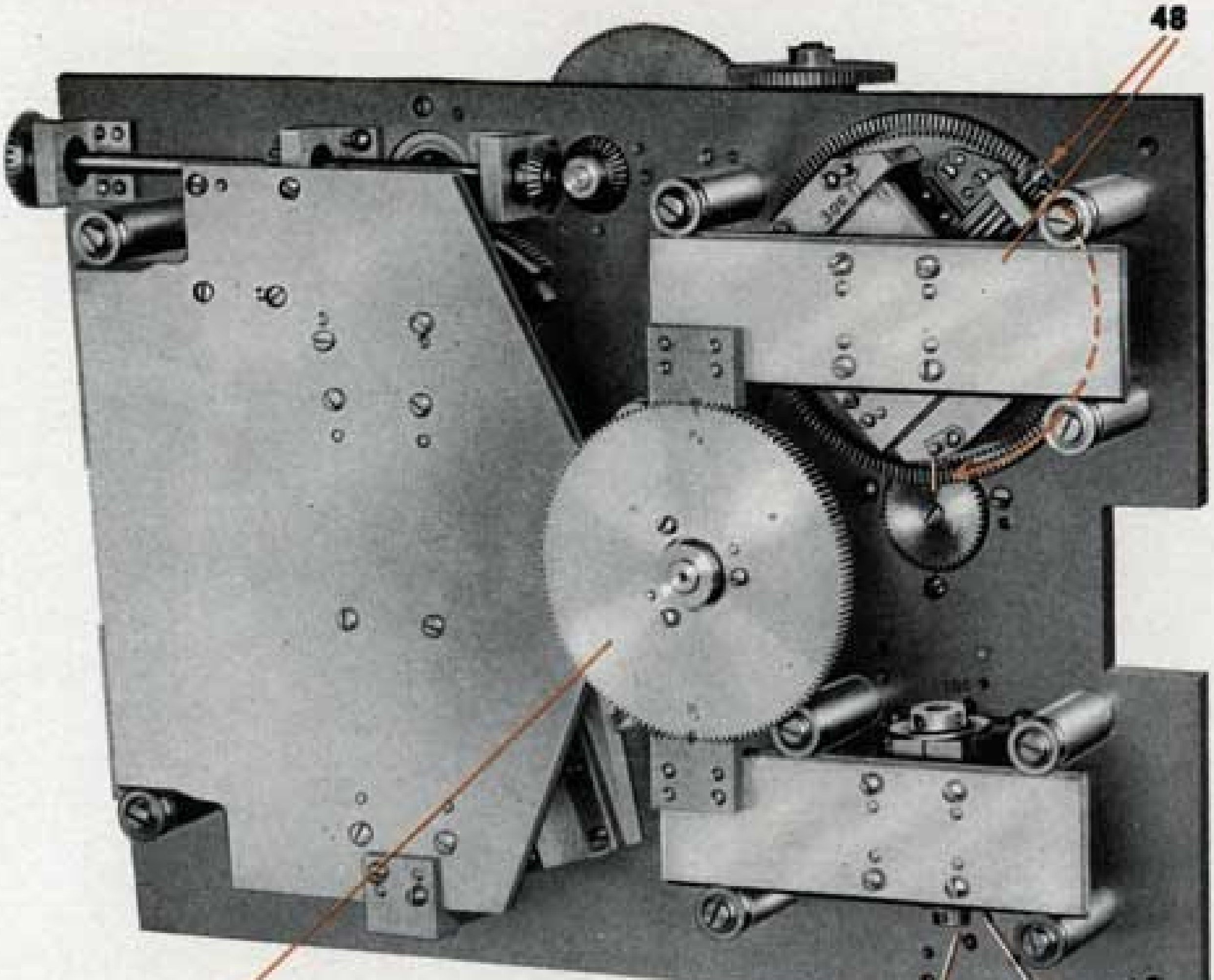


Fig. 208

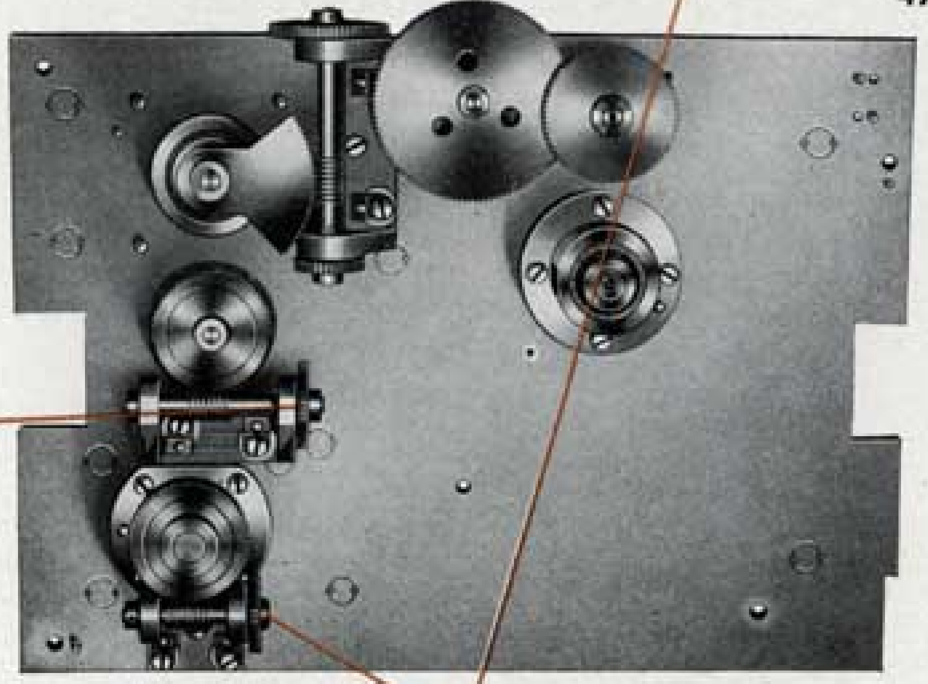


Fig. 209

51. Watching the dial indicator, vary the P2+3SR/2889 input until the indicator shows exactly 0.075" motion of the sine carriage. This is the 150 foot position of the P2+3SR/2889 input and the gears should be properly marked in case the existing marks do not line up.

52. Utilizing the zero marks on the A input gearing, set that gearing back to the zero position. A and Br are now each set on zero degrees, P2+3SR/2889 is set at 150 feet, and P1 is properly set for the Sound Base Line.

NOTE: It must be remembered that P2 = 150 feet is equivalent to 2P2 = 300 feet, $\frac{3SR}{2889}$ being zero.

53. Set the Range input on the Range Resolver until a dial indicator on the R tan (Br − Fr) carriage shows no motion when the pivoted arm is moved from one extreme to the other. This is the zero position of the Range input.

54. Turn the bronze bevel gear at the top exactly three turns in a counterclockwise direction, which will accurately determine the 300 yard position of the Range input. This position of the gearing should be marked.

55. Run the Range temporarily back to zero and with A and Br still set on zero as stated in step 52, replace the large differential gear, aligning the marks on it with the marks on the two racks with which it meshes.

56. Turn the Range up to 300 yards and prepare to install the Sound Bearing Converter on the chassis.

57. Check to see that Own Course and Relative Target Bearing are still set on zero degrees, Target Course is still set on 180 degrees, and Range is still set on 300 yards on the Position Keeper.

58. Carefully replace the Sound Bearing Converter making sure that all of the gear meshes go together properly and without any turning of any of the gears as otherwise synchronism would be lost. Secure the unit by means of the five screws. It is necessary that the screw which fits in the counter bored hole is properly seated below the surface.

59. Run the Target Length Stop to its minimum end (upper end), and secure it to the rear of the chassis.

Fig. 210

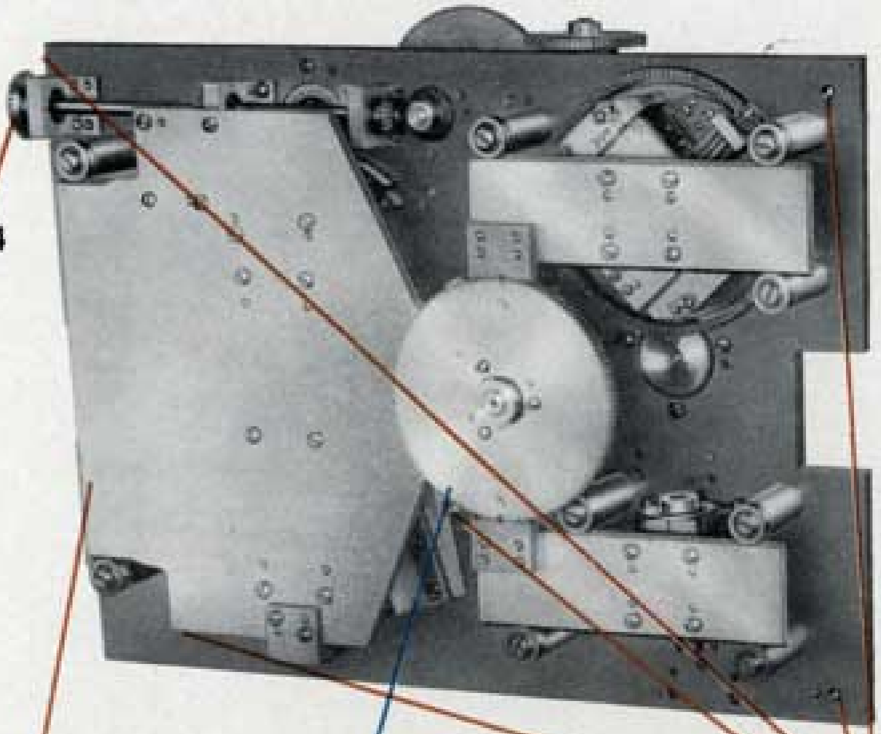


Fig. 211

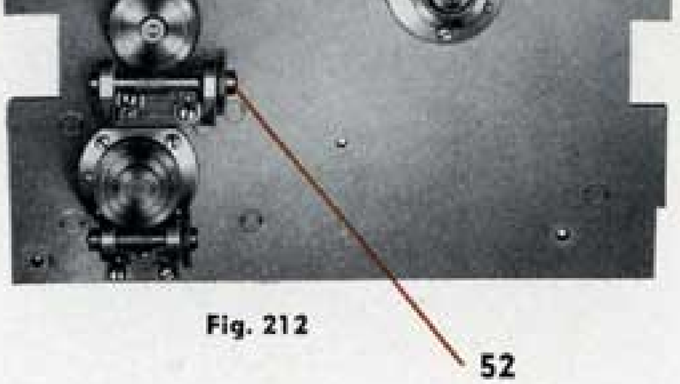


Fig. 212

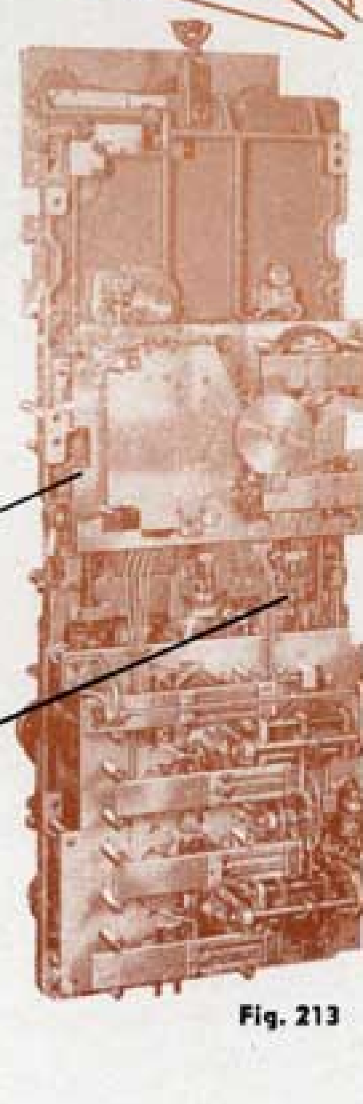


Fig. 213

60. By means of a synchro dial wrench set the Target Length Dial so that it reads 300 feet against the "O" graduation on the index plate.

61. Run the Range input up to 8000 yards by means of the 12 tooth steel spur gear which meshes with the Range input handle.

62. By means of a synchro dial wrench set the two Relative Sound Bearing Dials to read zero degrees against their respective index marks.

63. Turn the 12 tooth steel gear, which meshes with the Time Reset Handle in the back of the front cover, until any graduation on the Time ring Dial is aligned with the index line on the index plate.

64. By means of a synchro wrench, adjust the inner Time Dial to read zero. The two Time Dials are now synchronized with respect to each other. It is not necessary to synchronize them with respect to the Time Motor or the Time Motor Governor.

65. In order to set the three Synchro Follow-up Heads, located at the bottom of the index plate, it is first necessary to crank Own Speed and Own Course to zero.

66. Set each of the three units by the method described in steps 67 to 71 inclusive.

67. Remove the inner Dial by removing the three small retaining screws.

68. Set the Synchro Motor on electrical zero by connecting it electrically to a standard Synchro Generator which is set on electrical zero.

69. By means of a synchro dial wrench set the trolley assembly so that the two front rollers are on the synchronized segment which is marked with a white "O" and a white line.

70. Adjust the distance between the two rollers properly, so that the minimum dead space exists without completing the circuits of both fields of the motor at the same time.

71. Replace the inner dial, adjust it to read zero against the zero of the ring dial on the Follow-up Head (which is also against the index line on the index plate), and secure it by means of the three small screws.

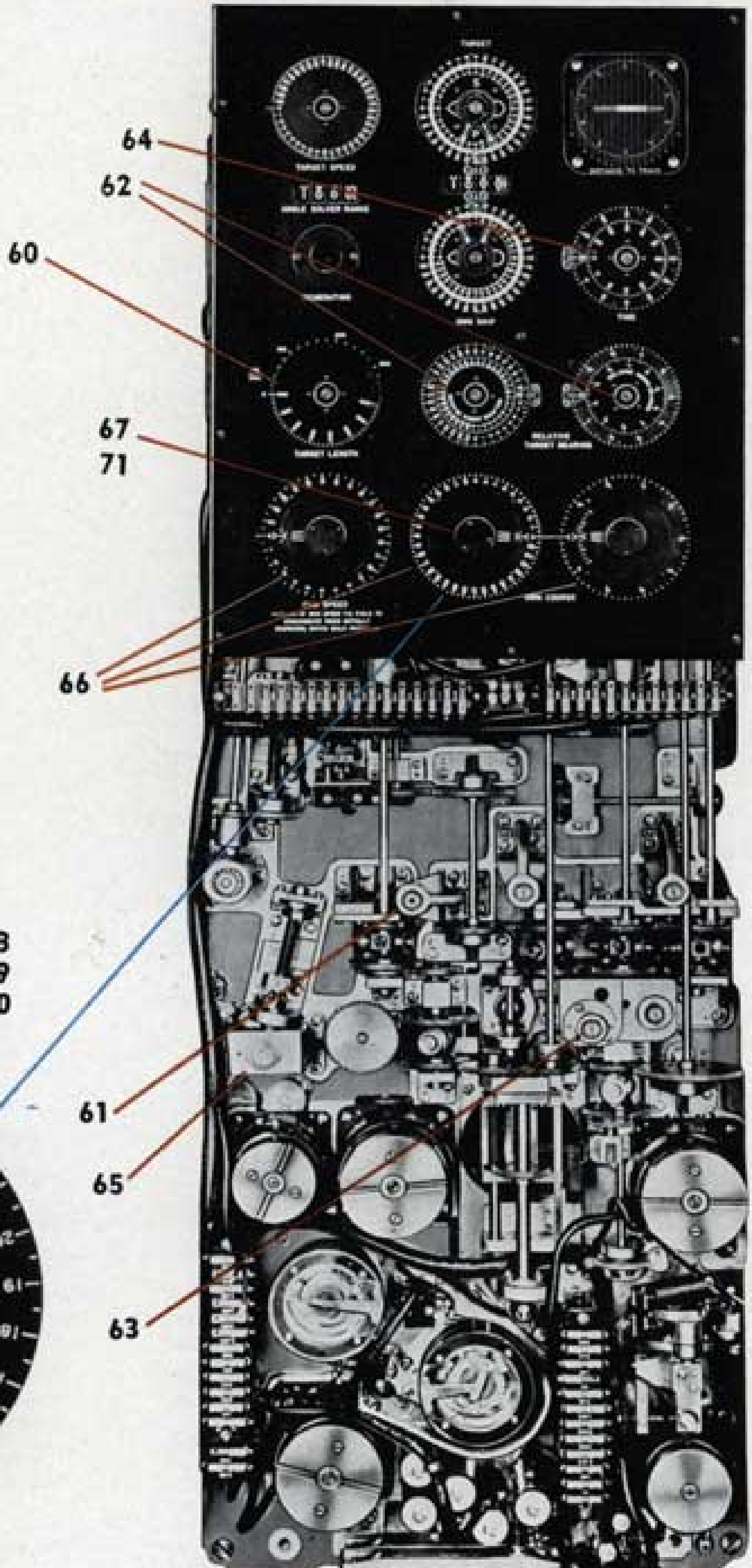


Fig. 214

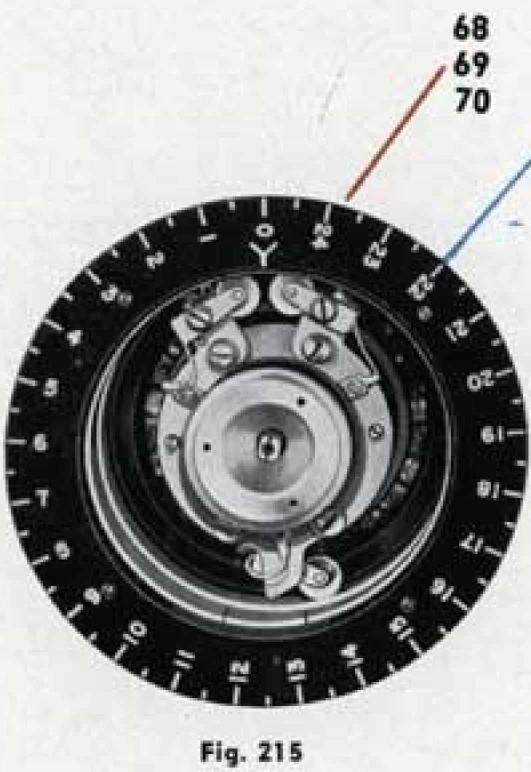


Fig. 215

The Position Keeper chassis is now completely reassembled and properly adjusted, with the exception of the Gyro Angle and Track Angle arrows on the Own Ship and Target Dials, these arrows being set only after the Position Keeper is coupled to the Angle Solver. The chassis may now be replaced and secured in its case by following the reversal of the procedure for its removal, as outlined on Page 152. Relative Target Bearing must temporarily be set to 135 degrees by turning the Relative Target Bearing hand input crank; and Angle on the Bow must be set to 135 degrees Port by turning the Target Course hand input crank. This is necessary in order that the carriages on the Integrator Unit clear the front edge of the case while the chassis is being replaced. After replacing the chassis, set Relative Target Bearing back to zero degrees, and set Target Course back to 180 degrees which will also set Angle on the Bow back to zero degrees.

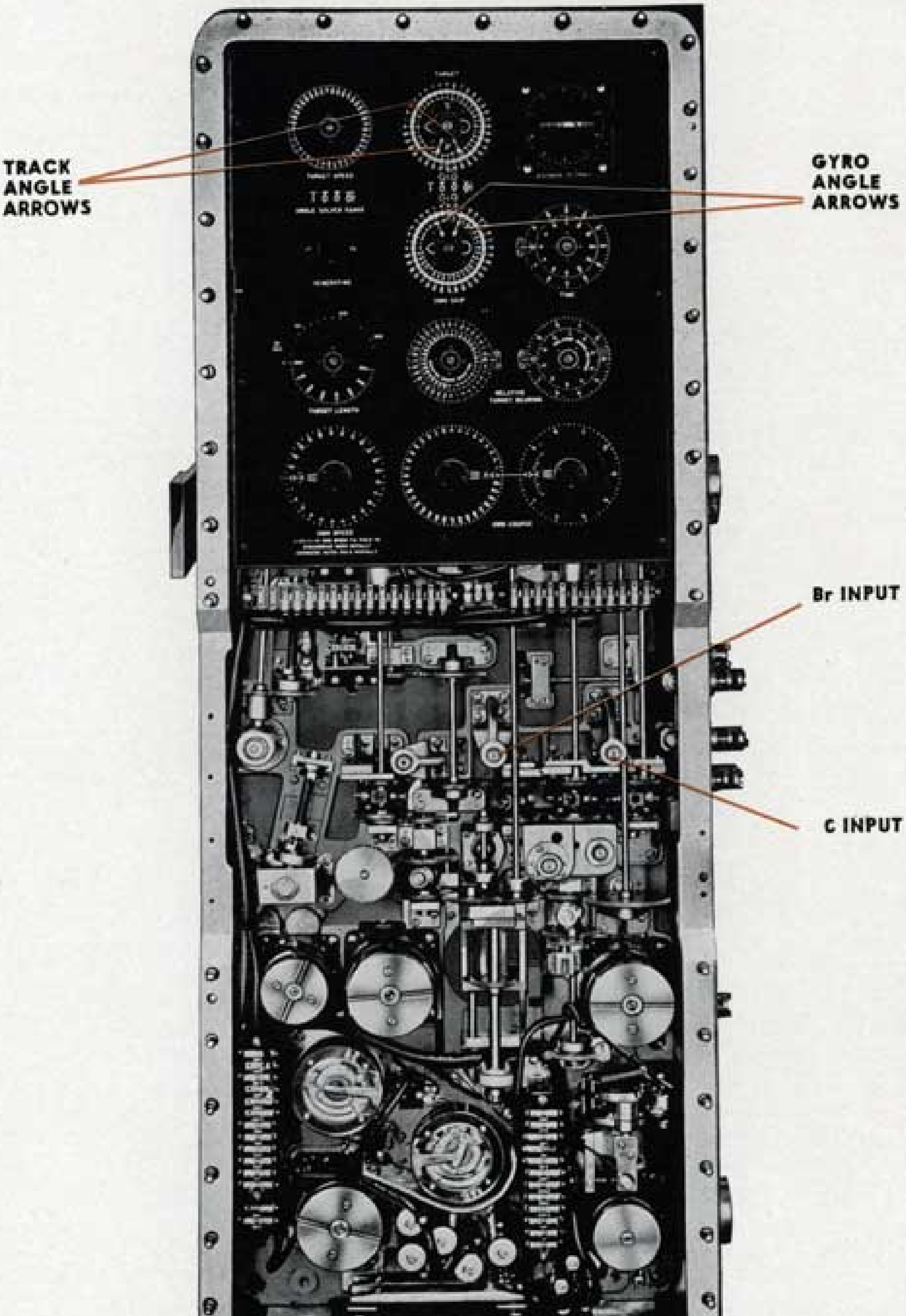


Fig. 216

REASSEMBLY OF ANGLE SOLVER CHASSIS

72. In reassembling the Angle Solver chassis, if it has been completely disassembled, it is first necessary to replace all of the brackets and adapters with attached gearing which were referred to in Step 75 of the disassembly procedure. It will then be necessary to replace the remaining units in the order which will be outlined in the following steps of this section. However, the three adapters just replaced (two I input and one $S'z$ input) which each support a shaft with a bevel gear on each end, should only be replaced loosely, and not secured until later during the reassembly procedure.

73. Place each bracket, with its 37 tooth steel spur gear, in its location on the rear of the chassis, and secure each with four screws.

74. Place each bracket, with its 56 tooth steel spur gear, adjacent to the brackets just secured, and fasten each from the front of the chassis with two screws.

75. Secure both Uy Stop Units on the rear of the chassis (three screws each).

76. Install the bracket and shaft which connect the Uy Stop gearing with the Uy gearing in the front cover (four screws).

77. Check the Resolver Units. Range (R) should be at 8000 yards when the Stop in the unit is set at its maximum end (the end away from the edge of the unit). Range is at 8000 yards when the Stop shaft has been turned exactly 60 turns in a counterclockwise direction from the zero Range position. Range is at zero when rotation of the G−Br angle carriage causes no motion of either the R sin (G−Br) or the R cos (G−Br) carriage. If, with Range at 8000 yards, it is found that the Stop in the unit is not at 8000 yards, or if the Stop prevents Range from going to 8000 yards, it must be remeshed until the Stop hits at exactly 8000 yards.

78. Check the Resolver Units. G−Br is on zero when increasing Range from zero causes the cosine carriage to move toward the center of the unit, and causes no motion of the sine carriage. If the zero paint marks do not become realigned, they should be replaced with new ones.

79. Check the Resolver Units. H is on zero when rotation of the Impact Angle, I, carriage causes no motion of either the H sin I or H cos I carriage. The zero pin should now be able to be pushed home in the steel spur gear of the H gear train, and if not, the various gears in the gear train should be remeshed until this condition is satisfied.

80. Check the Resolver Units. I is on zero when increasing H from zero causes the cosine carriage to move toward the center of the unit, and causes no motion of the sine carriage. If the zero point marks do not become realigned, they should be replaced with new ones.

DISASSEMBLY AND REASSEMBLY

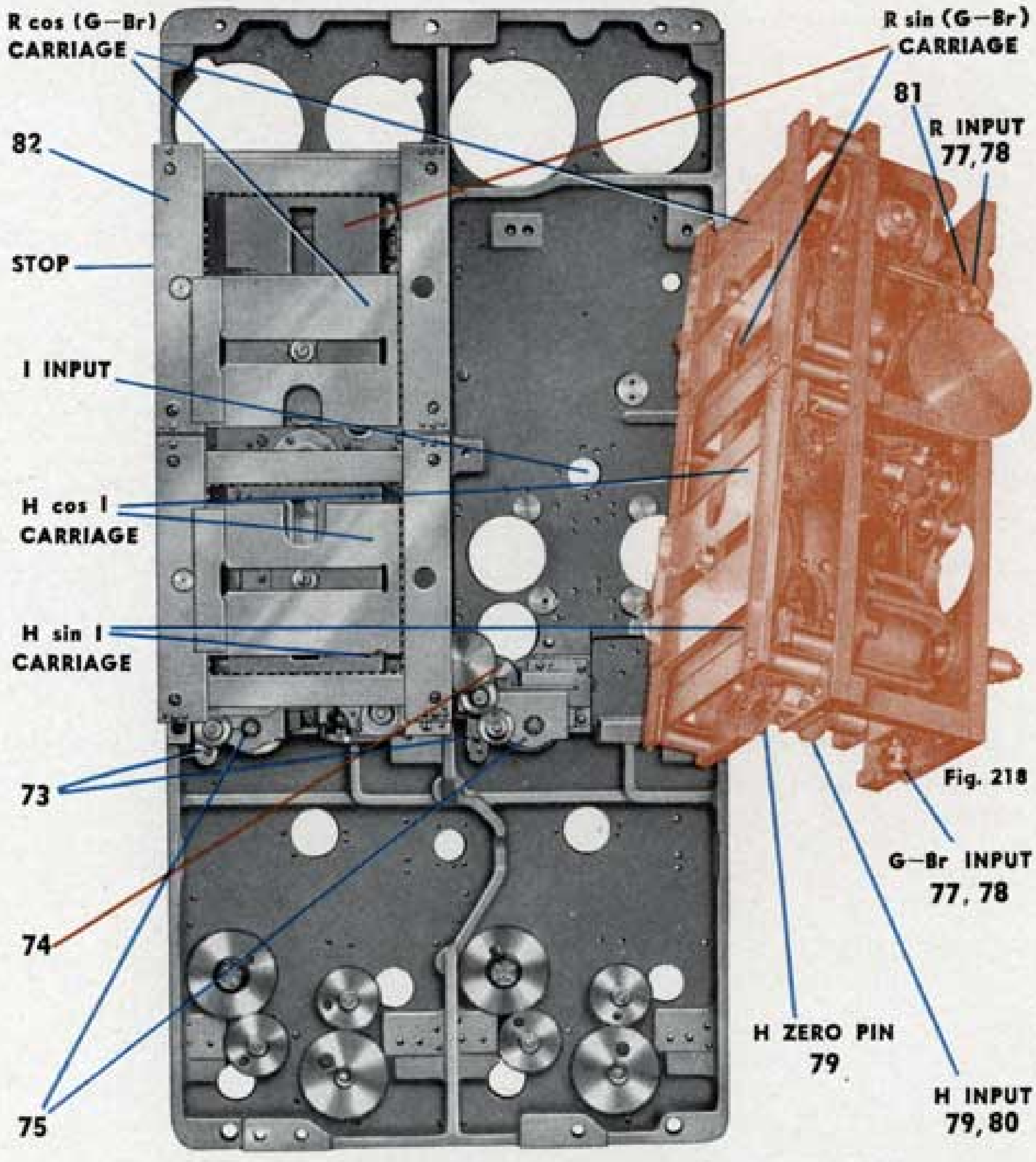


Fig. 218

Fig. 217

81. Determine whether or not the two halves of the couplings which connect the worm shafts of the Range gear trains of the two units will be aligned with each other when the two units are in place on the chassis, and the same value of Range (8000 yards) is set in on each unit. If not, this condition must be corrected before replacing the units, which in turn will necessitate resetting of the Range Stop of the unit being adjusted.

82. Place the fwd Resolver Unit on the chassis and secure it with its four hexhead bolts and one screw. The gear mesh made adjacent to the fwd Uy Stop Unit gearing is not synchronous.

83. Place the aft Resolver Unit beside the fwd unit, and secure it with its four bolts and one screw. The gear mesh made adjacent to the aft Uy Stop Unit also is not synchronous.

84. With both Range Stops set at 8000 yards as determined in step 77, connect the two coupling halves mentioned in step 81, by inserting the small coil spring between the two parts of the sliding half.

85. Set the traveling nuts of the fwd and aft Uy Stops at the same ends of their respective Stops (either end will do as long as both Stops are at the same end).

86. Connect the two Stops by installing the connecting shaft with its gearing. The two Stops are now synchronized with each other. The two Proportionator Units should be replaced after checking the setting of the three inputs. This is especially necessary if the units have been apart or if their Stops have been removed.

87. To determine the zero position of Target Speed S, adjust the gearing of the S input until no motion is obtained on the H output when the pivoted arm is moved from one extreme to the other.

88. If the S Stop is not set properly, remove it and set it to its zero end (left end, looking from the rear) and then replace it, meshing it with the rest of the S gear train while the train is in its zero position as determined in step 87.

89. Determine whether or not the two halves of the couplings, which connect the worm shafts of the Target Speed gear trains of the two units, will be aligned with each other when the two units are in place on the chassis, and the same value of Target Speed is set in on each unit. If not, this condition must be corrected before replacing the units, by varying the mesh between the spur gear and the Target Speed carriage which in turn will necessitate resetting of the Target Speed Stop of the unit being adjusted. This adjustment is not necessary if the units have not been disassembled. The zero position of S can now easily be determined, when desired, by turning the S Stop to its zero end.

90. Determine the zero position of the pivoted arm, by adjusting the arm until no motion is obtained on the H output when the S gearing is run from one end of the Stop to the other. Mark this position, if the existing marks are not properly aligned with their indices, on the 100 tooth worm gear (low speed mark) and on the shaft of

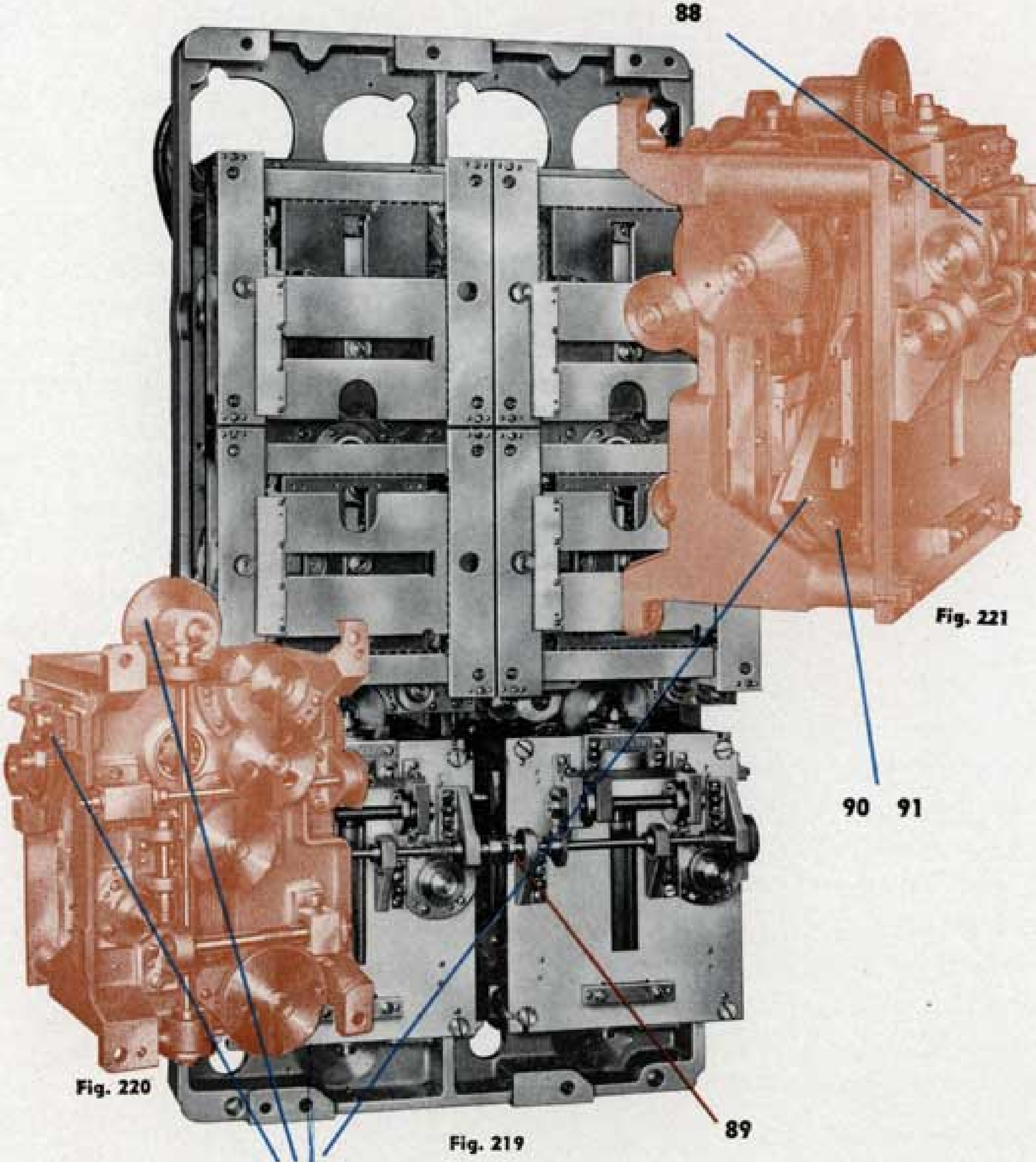


Fig. 221

Fig. 220

Fig. 219

the worm which meshes with this worm gear (high speed mark). The zero position of the pivoted arm can now easily be determined when desired, by aligning the marks just described.

The 25 knot position of the S'z input gearing can be determined in the following manner.

91. Set the pivoted arm at its zero position by the method described in step 90.

92. Mark the position of the 80 tooth steel spur gear in the Us+Ug−Uy output gear train.

93. Turn the worm shaft, which positions the pivoted arm, 171 turns in a clockwise direction, looking from the right of the unit.

94. Adjust the S'z gearing until the 80 tooth gear has moved 27 teeth in a clockwise direction, looking from the front of the unit. This is the 25 knot position of the S'z input and the S'z Stop should now be at its 25 knot end (on the fwd unit the right end, and on the aft unit the left end looking from the rear). This adjustment can be made by removing the taper pin from the bronze spur gear on the Stop shaft and unmeshing the gear, after which the gear can be remeshed and secured with the Stop properly set. It may be necessary to unmesh these gears beforehand, as the Stop, if improperly set, might prevent the S'z gearing from reaching the 25 knot position. The 25 knot position of S'z can now be determined, when desired, by turning the S'z Stop to its 25 knot end.

95. Set the H output of the fwd Proportionator Unit to the zero position by setting the S Stop at the zero end.

96. Check to see that the H input of the fwd Resolver Unit is in its zero position, with the zero pin in place as described in step 79.

97. The meshing of the H gears requires proper alignment of the gears. If it is seen that the alignment will not be obtained, it will be necessary to shift the mesh of the H gear on the top of the Proportionator Unit with the bevel gear that drives it, until the alignment is obtained. This is done by removing the two screws which secure the bracket mounting the gear, and loosening the bracket until the gear mesh is broken. Then, by shifting the bevel mesh a tooth at a time correct alignment will finally be obtained. By using this procedure, it will not be necessary to repin the bevel gear driving the H output gear of the Proportionator Unit, which otherwise might be necessary.

98. After the H gear mesh has been satisfactorily made, secure the unit with four bolts and two slip dowels.

99. *Remove the zero pin.*

100. Connect the G−Br coupling between the fwd Resolver Unit and the Proportionator Unit. The connection is not synchronous.

101. Set the aft Proportionator Unit in place and mesh the H gears by using the procedure outlined in steps 95 and 97.

102. Secure the unit with four bolts and two slip dowels.

103. *Remove the zero pin.*

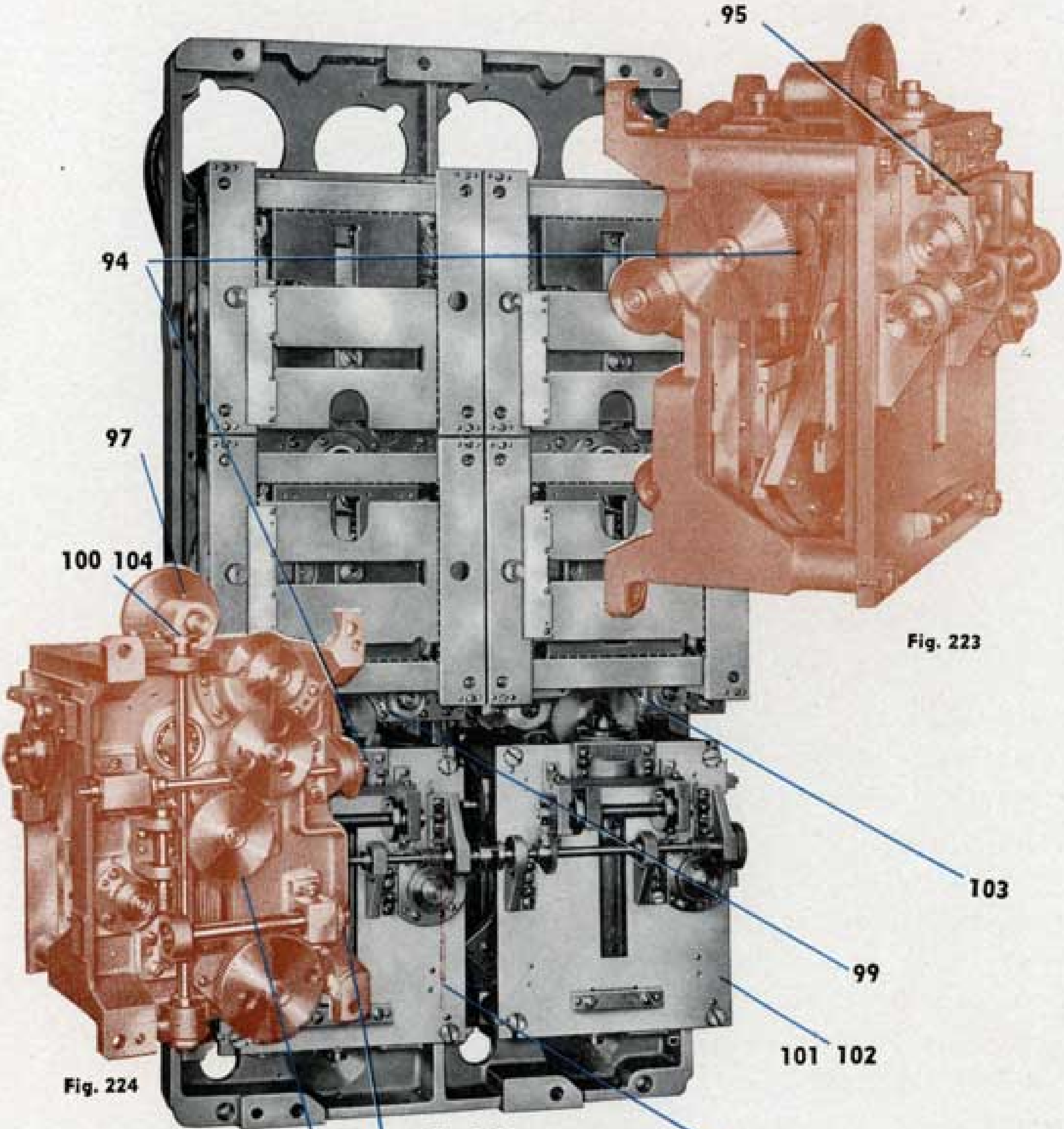


Fig. 223

Fig. 224

Fig. 222

104. Connect the G – Br coupling which is not synchronous.

105. Set the S Stops of both Proportionator Units at their zero knot positions, and connect the two halves of the coupling between the S gear trains of the fwd and aft units.

106. With each S'z Stop set at 25 knots, replace securely (from the front of the chassis) the adapter the rear bevel gear of which meshes with the bevel gears in the S'z input gear trains of the Proportionator Units.

107. Replace the two adapters the rear bevel gears of which connect with their respective I Input bevel gears on the two Resolver Units, and secure each with three screws.

108. Adjust the pivoted arms of each Proportionator Unit until no motion is obtained on the H output gears when the S Stops are run from one extreme to the other. The arms are now in the zero positions.

109. Set the two $\tan^{-1}$ T'a Stops to their zero positions, that is, when the traveling nuts are at the driven ends.

110. Replace the two Stops and secure each with four screws. Set G−Br at zero in the Resolver Units according to the method given in step No. 78.

111. Set the G−Br Stops on the front of the chassis at their zero positions, that is, with the traveling nut 22½ turns from either end.

112. Secure each Stop in position with four screws.

113. Secure in place the four Synchro Generators at the top of the chassis.

114. Secure the brackets which support the gearing which drives the Synchro Generators.

115. The Offset Angle Stop in each Differential Unit must be set at its zero position. This can be determined by running the Stop to either end and then turning the 63 tooth steel spur gear exactly 5-5/6 turns, upon which the switch actuating cam should operate the switch. Because of the fact that the switch is not connected electrically to the magnet at this time, the detent apparatus will work every time the Stop shaft makes one revolution, and one of these times will be now, when the Stop is in its zero position.

116. Replace each Differential Unit and secure it by means of four screws.

117. Connect the three couplings between the two units. At this stage of the procedure the meshing of the three couplings, and the meshing of the three gear meshes of each unit with their respective gears on the chassis is not synchronous.

118. Secure in place the long bronze shaft (with its three supporting brackets and gearing).

119. Replace the Torpedo Run limit switch mounting bracket, and secure it with three screws.

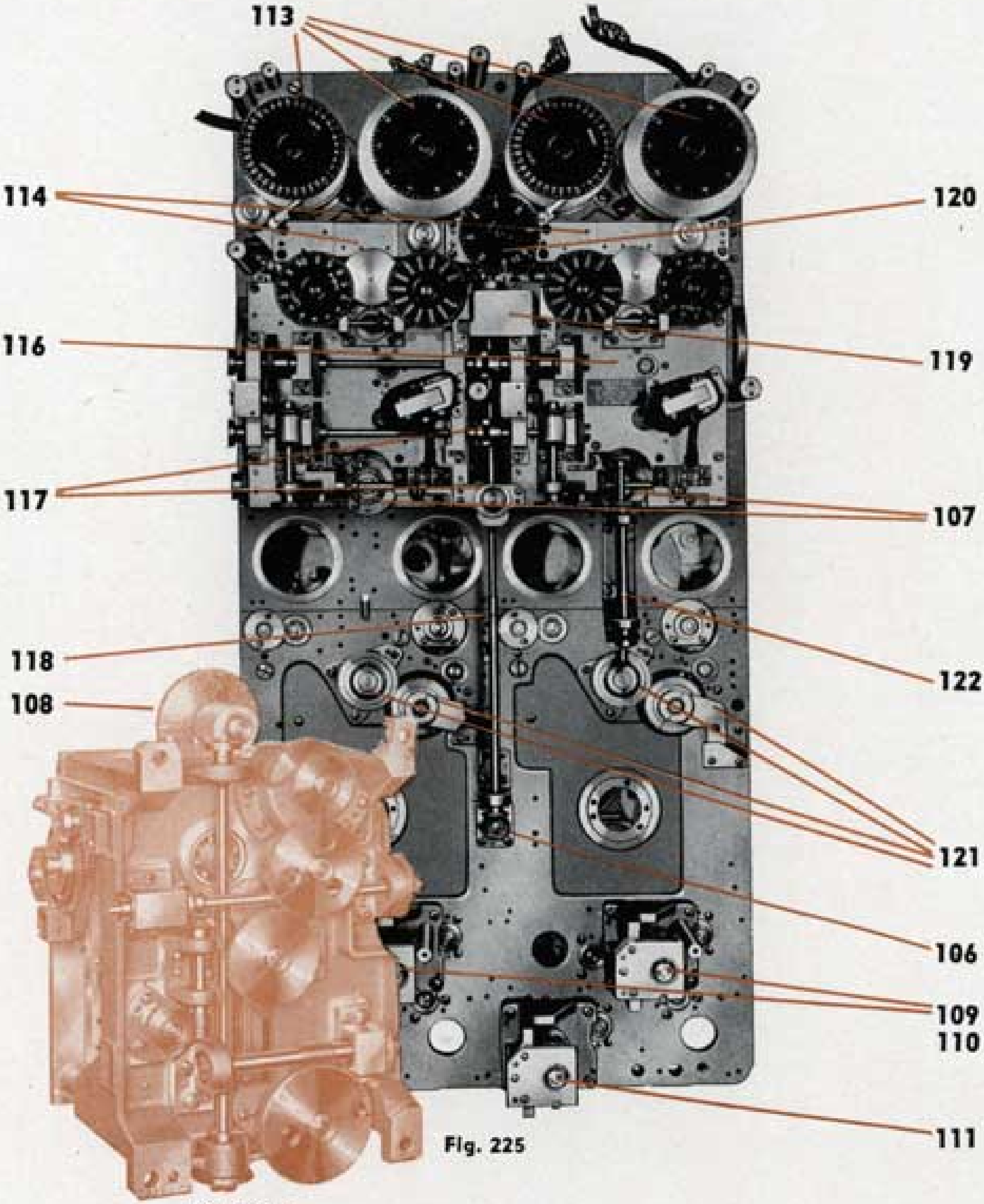


Fig. 225

Fig. 225 a

120. Replace and secure the Depth Set Dial mounting bracket with its black dial only.

121. Replace the four brackets (with gearing) below each Differential Unit, if not already in place.

122. Replace the connecting bracket, with its shafts and gearing, below the fwd Differential Unit and between the two fwd Follow-up Heads.

123. Replace the connecting bracket, with its shafts and gearing, below the aft Differential Unit and between the two aft Follow-up Heads.

124. Replace the small bracket with its gearing at the left of the lower part of each of these two connecting brackets. Secure each with three screws.

125. Near the right end of each of the two large steel gear segments draw a pencil mark three teeth from this end. This mark is to be drawn radially, so that it would pass through the center of rotation of the segment, if extended that far.

126. Mesh the right end of each gear segment (turning it clockwise) with the respective Differential located above, and turn the segment until the pencil line is aligned with the imaginary line drawn from the center of rotation of the segment to the center of the Differential.

127. With the segment in this position, draw a pencil mark on the bronze gear above (the bronze gear being on the Resolver Unit), which drives the Us+P cos G Follow-up Head.

128. Draw a pencil mark on the Resolver Unit plate, aligned with the mark on the gear. Now the segment can be set in its three-teeth-from-the-end position, when desired, by observing the mark on the bronze gear, provided the gears have not been unmeshed, and it is known that the segment is somewhere near the desired position and not far enough away to rotate the bronze gear and its mark one complete revolution.

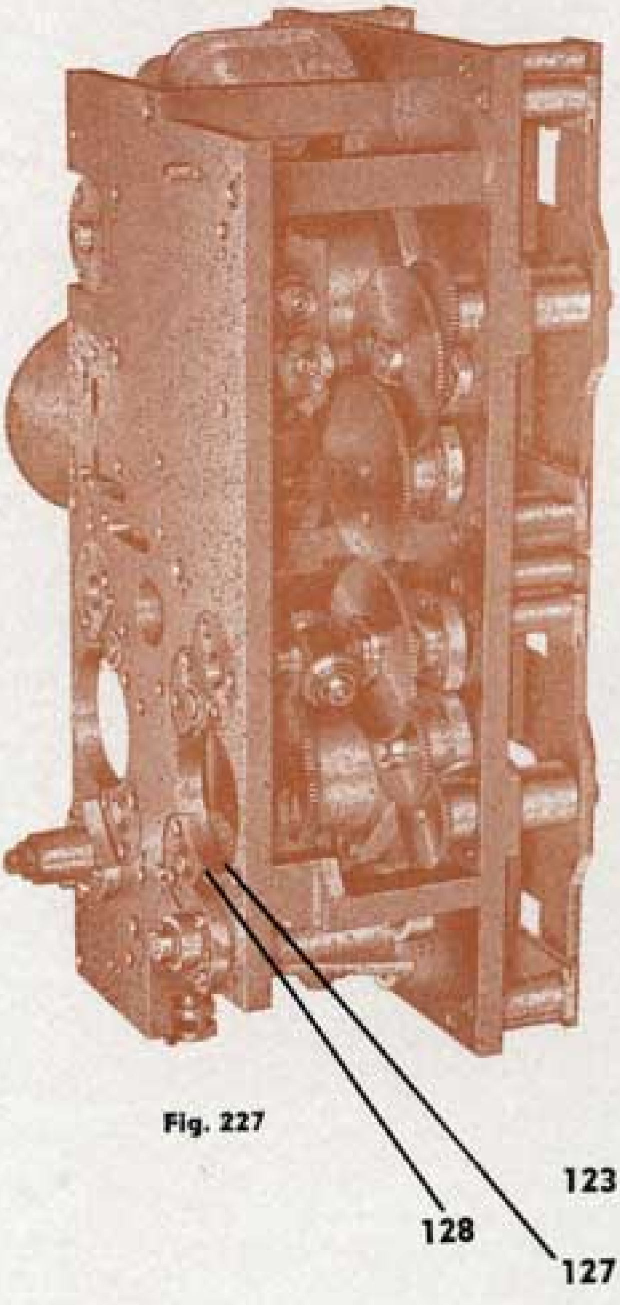


Fig. 227

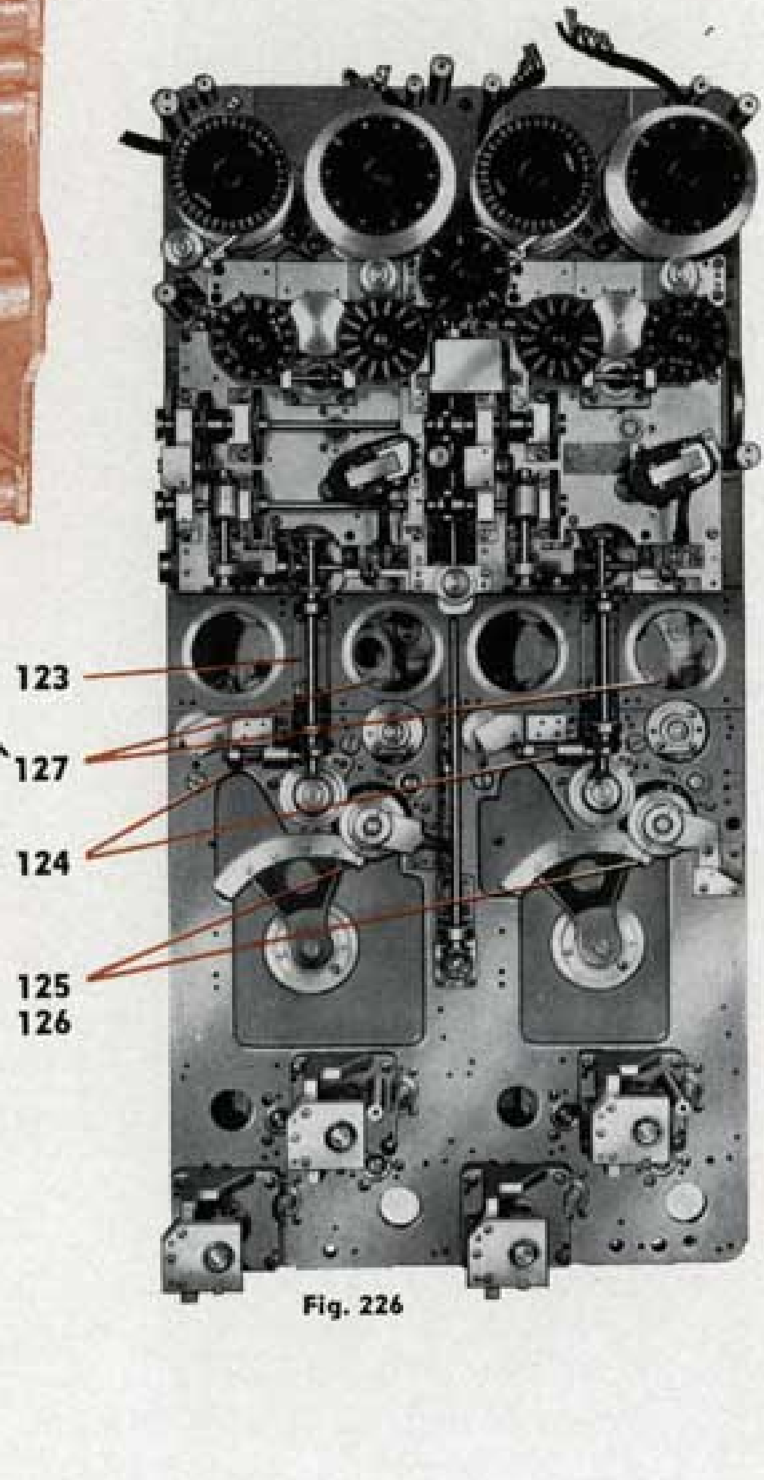


Fig. 226

Set each cam unit as follows:

129. Slide the M carriage to the right.

130. Turn the Gyro Angle input gearing of the unit until the engraved index mark can be seen adjacent to the circular engraved band.

131. After the engraved mark comes into view, hold the Gyro Angle input securely and slip the band (using a screwdriver in the notches of the band) until the 100 is aligned with the engraved mark. CAUTION: In adjusting the band, never go below 0 or above 100, or damage to the Resolver may result.

132. Set the Gyro Angle input gearing in the zero Gyro Angle position on the fwd Cam Unit.

133. Set the Gyro Angle input gearing in the 180 degree Gyro Angle position on the aft Cam Unit, by aligning their marks. The low speed marks are scribed on the Base Line Resolver on the left side of the unit. The mark on the rotating carriage of the Resolver must be aligned with the index mark on the housing within which the carriage rotates. The high speed marks are scribed on the bronze spur gear seen in the top of the cam unit and on the small steel finger adjacent to this gear.

134. With the inputs set as above, set the fwd Cam Unit in place and secure it with its six screws. The $Ug - P \cos G$ output rack on the back of the cam unit must mesh properly with the small gear on the steel gear segment previously set. The setting can be checked by the pencil mark made on the bronze gear in step No. 127. A slight variation of this gear from the aligned position is permissible in order to facilitate the meshing of the rack with the small gear on the segment. After meshing, do not attempt to turn the bronze gear further, as this would feed back into and force the gearing within the cam unit. The $J + P \sin G$ output segment in the cam unit must mesh with the gear on the chassis so that an equal number of teeth on the segment are on each side of the meshing point. This depends on the internal mesh of the $J + P \sin G$ gearing within the cam unit.

135. Also with the inputs set as above, set the aft Cam Unit in place and secure it with its six screws, following a similar procedure.

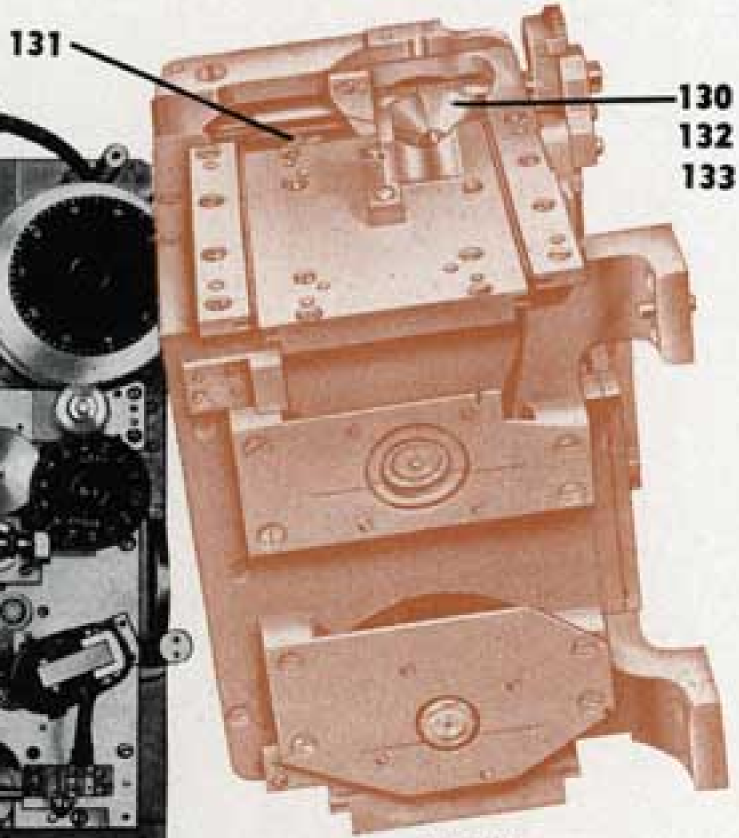


Fig. 229

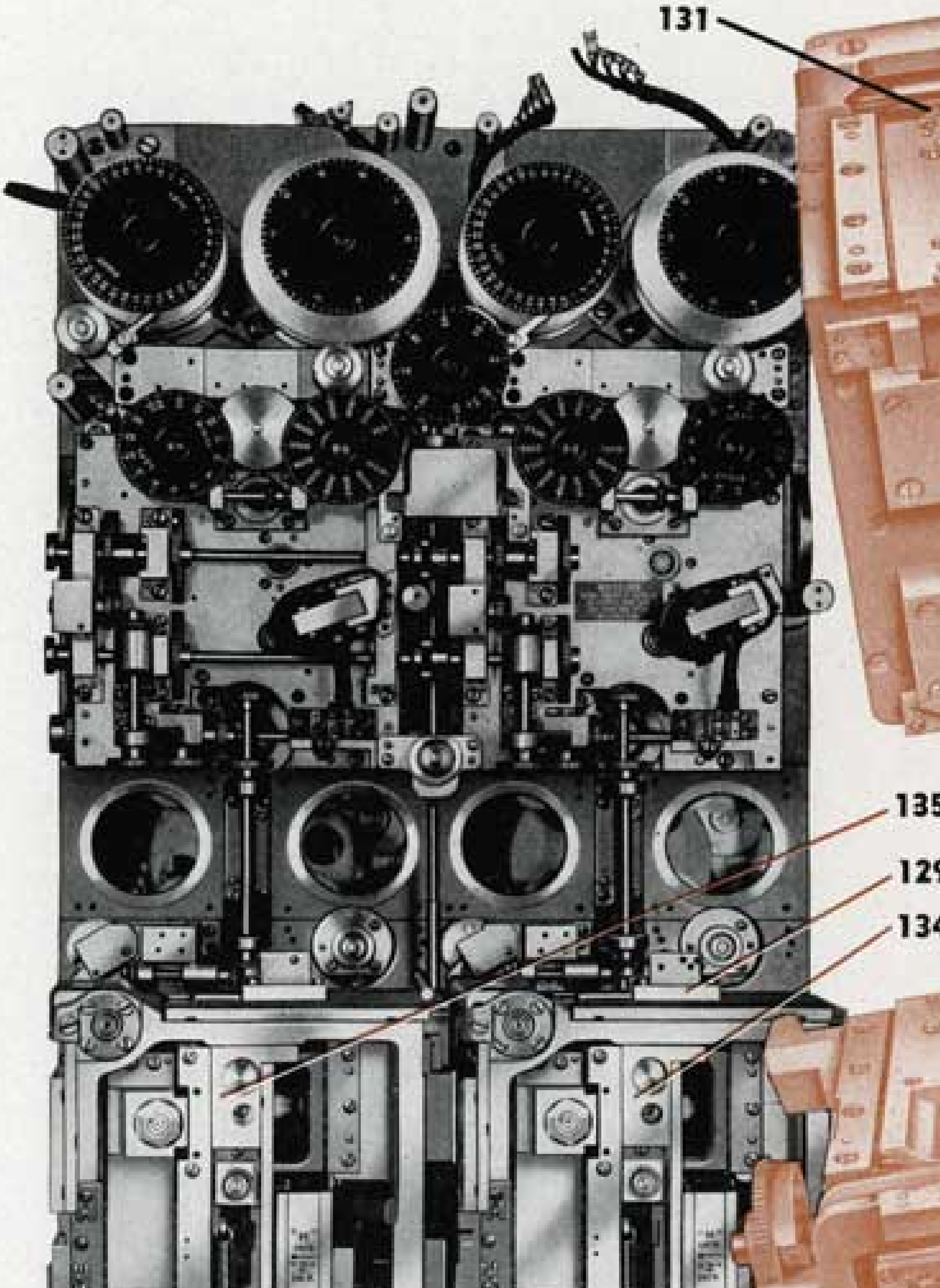


Fig. 228

Fig. 230

136. Slip the front bracket on the Uy input shaft and secure the bracket to the fwd Cam Unit with its two slip dowels and two screws.

137. Replace the gear on the front end of the shaft.

138. Replace the high speed Gyro Angle input gear and bracket, thus connecting the fwd Cam Unit input gearing to the gearing on the chassis. Secure the bracket with its two slip dowels and two screws.

139. Connect the two M carriages by means of the connecting link, and secure the link with its two screws.

140. Connect the two Z carriages by means of the connecting link, and secure the link with its four screws.

141. Check that the G—Br Stops are still in their zero position. If they are not, reset them until they are, with the traveling nut 22½ turns from either end.

142. Check that the Offset Angle Stops in the two Differential Units are still set in their zero positions. If they are not, reset them until they are.

143. Check that the Gyro Angle input of the fwd Cam Unit is still in its zero position (zero Cam and zero Gyro Angle), and if it is not, reset it until it is. Relative Target Bearing, Br, will now be at zero degrees.

144. Temporarily replace the dial index plate.

145. Set all four Gyro Angle dials on zero degrees, using a synchro wrench for their adjustment.

146. Set the two Offset Angle dials on zero degrees.

147. Turn the Br shaft in the left of the aft Differential Unit until the Gyro Angle dials read 180 degrees.

148. Check to see that the G—Br Stops are still in their zero positions.

149. Check that the Gyro Angle input of the aft Cam Unit is still in its 180 degree Gyro Angle position, and if it is not, reset it until it is.

150. Replace the high speed Gyro Angle input gear and bracket in the aft Cam Unit, thus connecting the aft Cam Unit input gearing to the gearing on the chassis. Secure the bracket with its two slip dowels and two screws.

151. Turn the Br shaft until the Gyro Angle dials read zero degrees, and clamp the shaft.

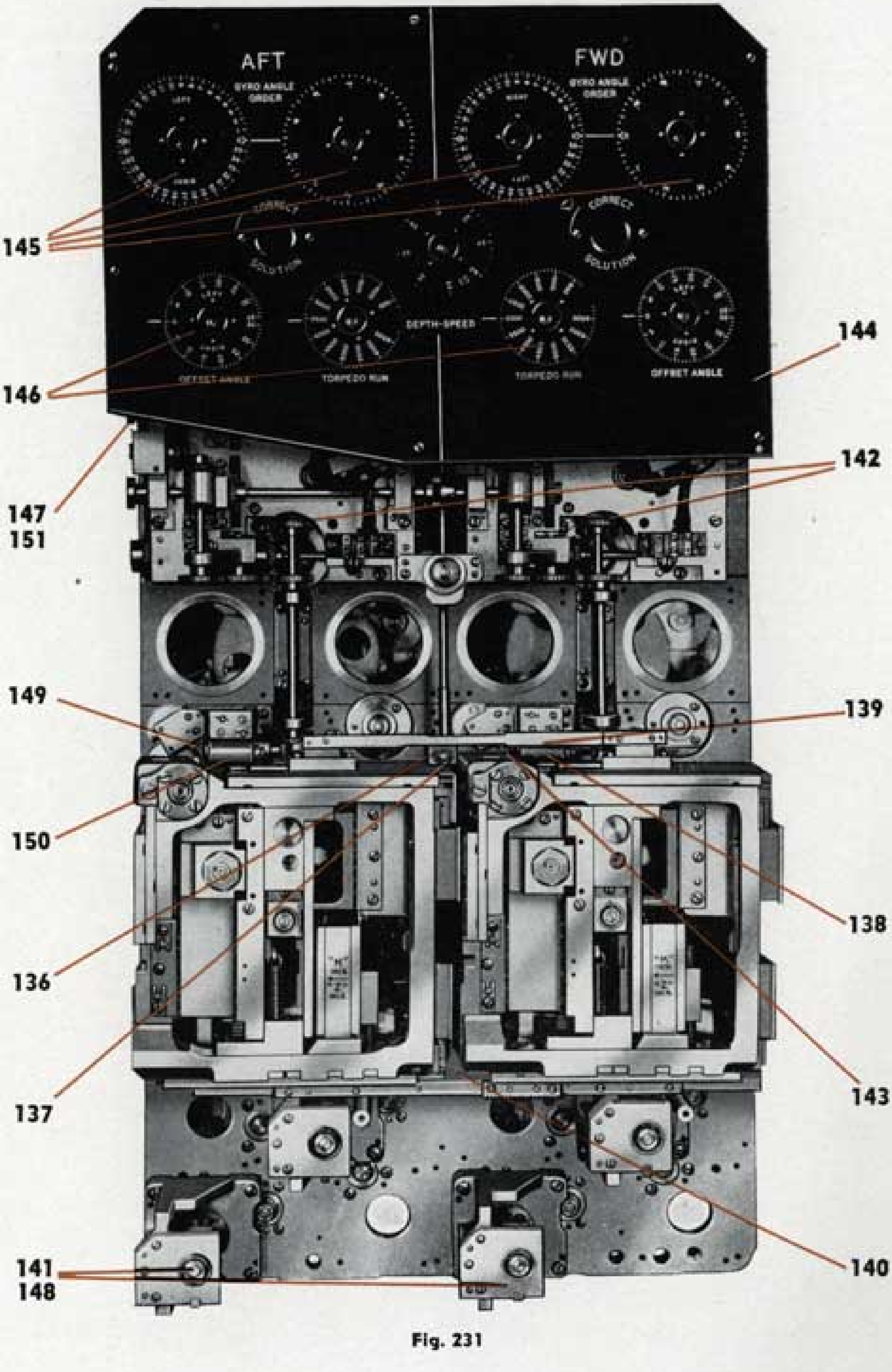

AFT
FWD
GYRO ANGLE ORDER
GYRO ANGLE ORDER
CORRECT SOLUTION
CORRECT SOLUTION
DEPTH-SPEED
OFFSET ANGLE
TORPEDO RUN
TORPEDO RUN
OFFSET ANGLE
145
146
147
151
149
150
136
137
141
148
144
142
139
138
143
140

Fig. 231

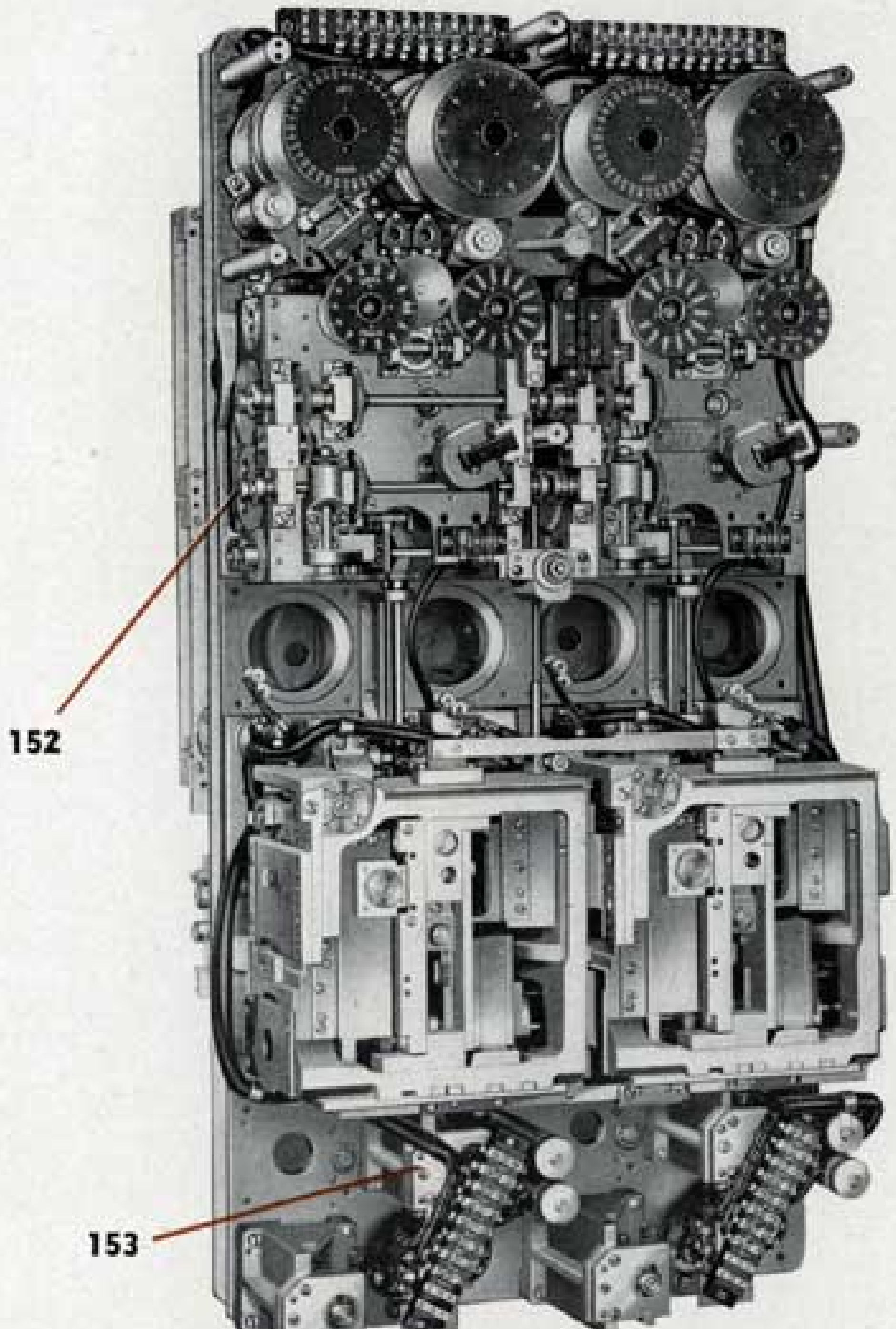


Fig. 232

152. Turn the A shaft in the left of the aft Differential Unit until the I'_a input of the aft Resolver Unit is at zero degrees. This may be checked as follows:

153. Run the aft $\tan^{-1}T'a$ Stop up to its maximum position (traveling nut at front end of Stop) which sets the pivoted arm within the aft Proportionator Unit in its maximum position.

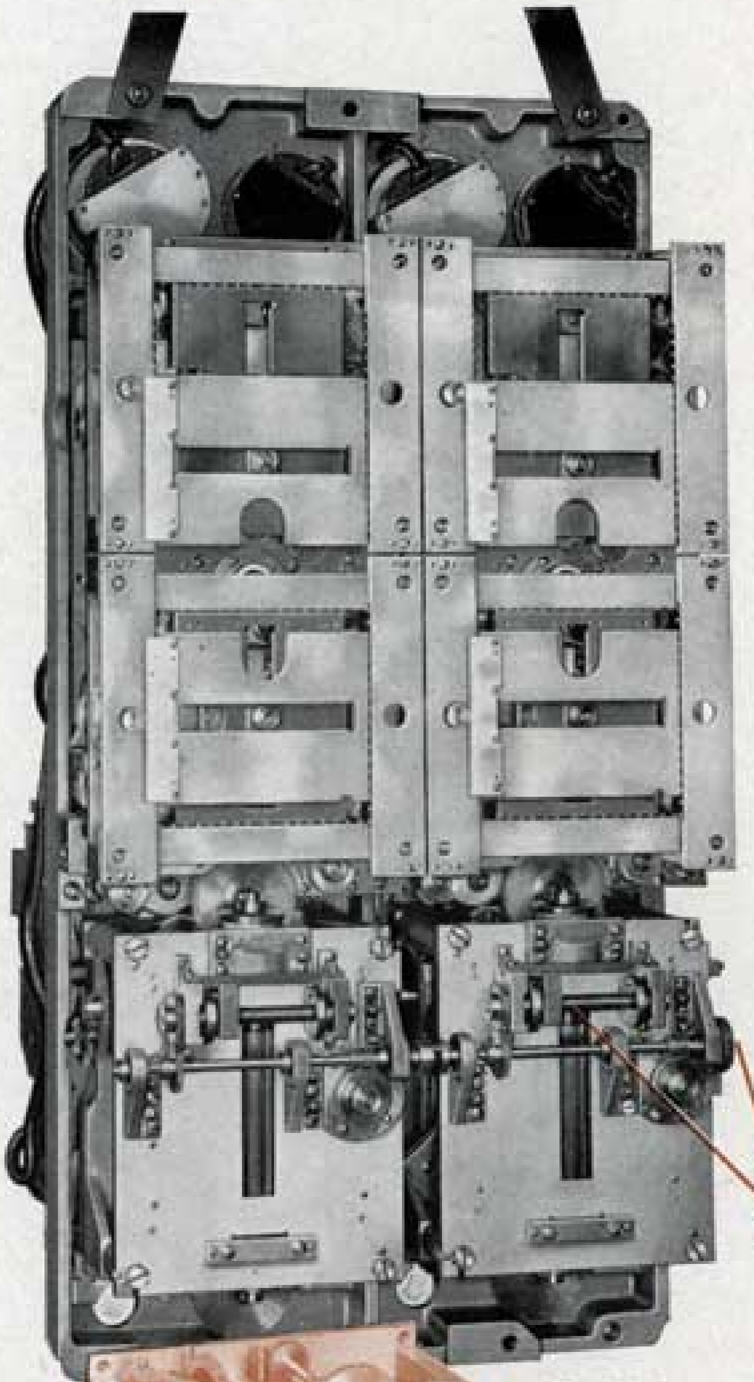


Fig. 233

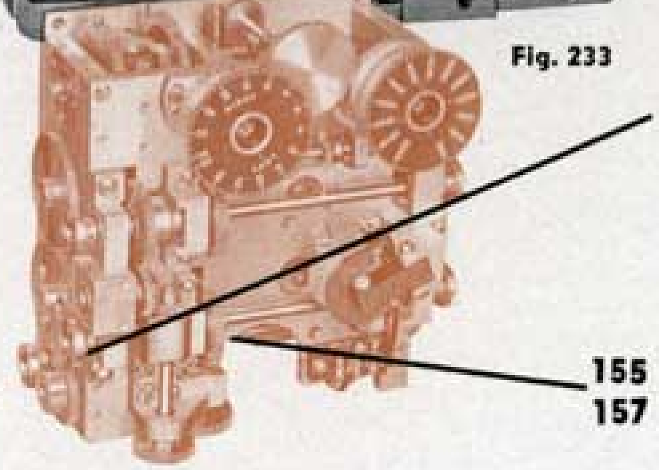


Fig. 234

154. Turn the S input on the back of the Proportionator Unit so that the traveling nut of the S Stop moves from left to right (increases), looking at the rear of the unit. This increasing of S causes the H output to feed into the Resolver Unit in an increasing sense, and I is on zero degrees when increasing H gives no sine output, but does cause the cosine output carriage to move toward the center of the Resolver Unit. The paint marks on the I input shafting should now be properly aligned.

155. If the I input of the fwd Resolver Unit is not at zero also, unmesh the 57 tooth steel gear on the fwd Differential Unit from the one within the unit. This requires removing the dial plate, followed by removing the securing screws and loosening the brackets of the gear.

156. When the unmeshing has been accomplished, vary the I input of the fwd Resolver Unit until it is in its zero degrees position which may be checked the same way as was done for the aft Resolver Unit.

157. Remesh the 57 tooth gear. Both I inputs are now at zero degrees for a given position of the A input shaft.

158. Clamp the A shaft in this position.

159. Turn the S'z gear on the front of the Angle Solver in a counterclockwise direction until it will go no further.

160. Replace the dial plate and set the S'z black Dial to read 25.

161. Turn the Uy gear on the front of the Angle Solver in a clockwise direction until it will go no further.

162. See that both $\tan^{-1}$T'a Stops are in their zero positions (traveling nut at driven, or rear end). The fwd Stop must be so set in order to replace the chassis in the case.

163. Set both Torpedo Run Dials in their zero positions. This can be done first setting the dial so that the 500 yard mark is aligned with the index mark, and by making a pencil mark on the dial plate at the 1000 yard mark. Moving the dial so that the 500 yard mark is aligned with the pencil mark will set the dial in its zero position and it can be secured while so set.

164. Replace the terminal blocks and any resistors, condensers or switches not yet in place, and then connect all inter-connecting wiring.

165. Replace and secure the chassis in its case by following the reversal of the procedure for its removal, as outlined in steps 18 to 30 of Disassembly.

166. Replace and secure the four Follow-up Motors.

167. If necessary to use the screw jacks in order to replace the chassis, remove the aft G−Br Stop 21A after checking that G−Br is at zero. As soon as the chassis is secured in place, replace the G−Br Stop while in its zero position, making certain that the G−Br gearing was not moved.

168. Turn the Target Speed coupling in the left side of the Angle Solver in a clockwise direction until the Target Speed Stops in the two Proportionator Units hit their zero knot ends.

169. Turn the Range coupling in the left side of the Angle Solver in a counterclockwise direction until the Range Stops in the two Resolver Units hit their 8000 yard ends.

170. Check the reading of the Angle Solver Range Counter in the Position Keeper which should read 8000 yards.

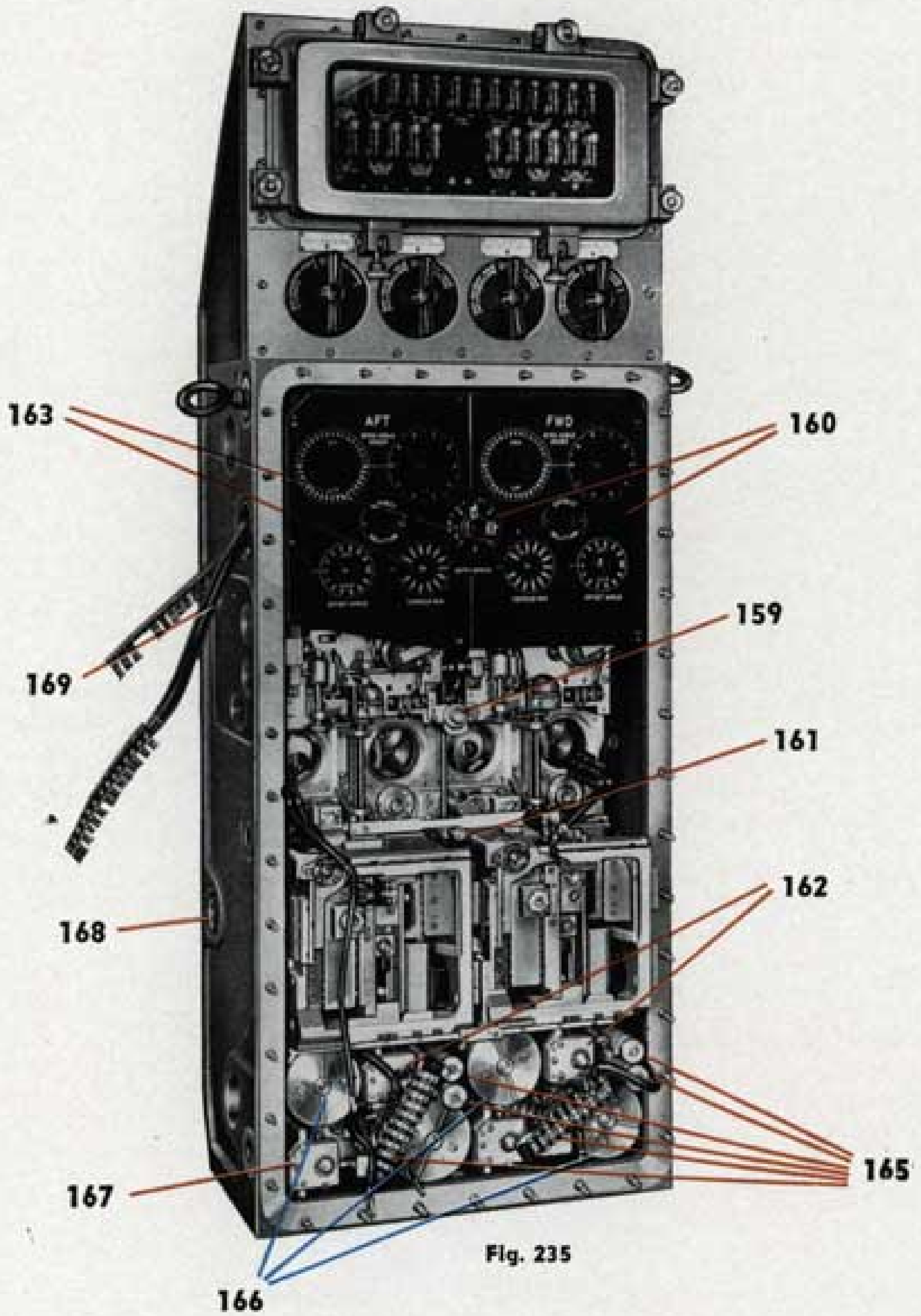


Fig. 235

171. Check Target Speed in the Position Keeper to see that it is at the zero knot value as indicated by the Target Speed Dial and Stop.

172. Check that Own Course and Relative Target Bearing are still set on zero degrees in the Position Keeper.

173. Check that Target Course is still set on 180 degrees.

174. Place the two sections on their large bottom connecting plate with its key and slide the sections toward each other.

175. Sight the alignment of the respective coupling halves, disregarding the G – Br couplings as their connection is non-synchronous. Each of the other four coupling halves must be in perfect alignment however, and if not, then the adapter of each misaligned coupling must be loosened in the Position Keeper case. Without disturbing the setting of any of the shafts, turn the misaligned couplings, after loosening the adapters just enough to break the gear meshes in the Position Keeper, until misalignment no longer exists, and secure the adapters. In case the S, Br, R, and A couplings can not be aligned by this method, the gears on the shafts must be relocated by removing the taper pins and using larger pins in the holes. This is done after the holes have been reamed with the gear in the correct position.

176. Secure the two cases together, first feeding the wiring from the Angle Solver case into the Position Keeper case. In order to replace the upper of the three bolts connecting the two cases in the front, the Position Keeper dial plate must be temporarily removed, after which it should be replaced.

177. Replace the remaining bolts in front, the two bolts and the plate in the back and the bolts in the bottom plate.

178. Remove the clamps from the A and Br shafts in the Angle Solver.

179. Connect all remaining wiring in the Position Keeper case.

180. With G – Br in the Angle Solver still set on zero degrees, remove the fwd Track Angle arrow and the fwd Gyro Angle arrow from the Target and Own Ship Dials with a synchro dial wrench.

181. Loosen the three screws which secure the aft Track Angle arrow and the aft Gyro Angle arrow and adjust them until they extend toward each other and are aligned with their respective indices.

182. After securing the aft Track Angle arrow and the aft Gyro Angle arrow, replace the fwd Track Angle arrow and the fwd Gyro Angle arrow and secure them while they are extended toward each other, and are aligned with their respective indices.

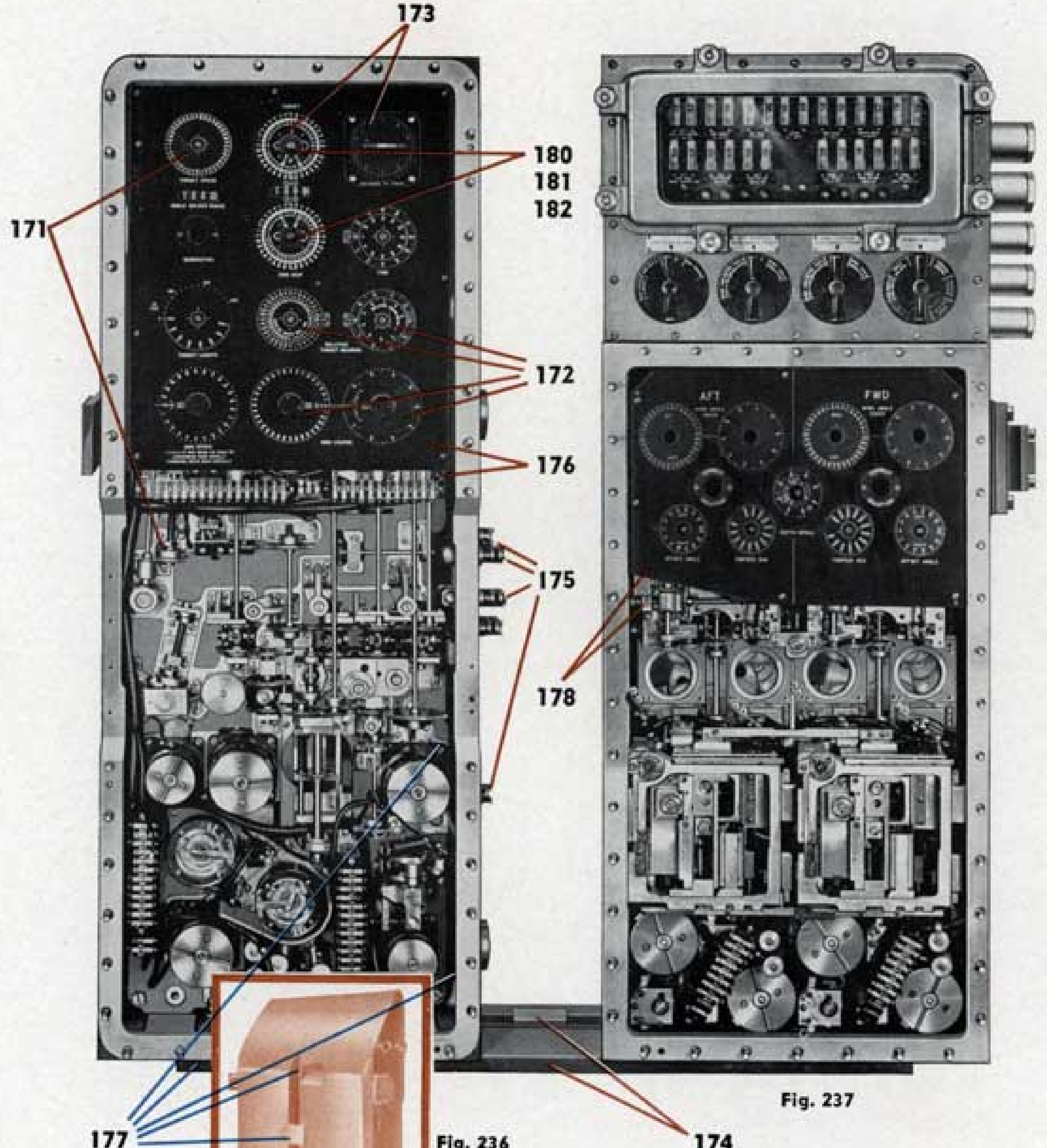


Fig. 236

Fig. 237

183. Replace the middle cover of the Position Keeper. Care should be exercised in remeshing the gears in the back of this cover with the gears on the front of the Position Keeper chassis. Also, just before the cover is on the case, the wiring of the two switches on the back of the cover must be connected.

184. Replace the other two front covers of the Position Keeper.

185. Check that Relative Target Bearing and Own Course are on zero degrees and that Target Course is on 180 degrees, as set in the Position Keeper.

186. Turn the fwd G – Br Follow-up Motor until the fwd Gyro Angle Order Dials read zero degrees.

187. The fwd G – Br Stop is now on zero degrees. Set the Range at 8000 yards.

188. Set H in its maximum position by setting the fwd $\tan^{-1} T'a$ Stop in its maximum position and setting Target Speed, S at 40 knots.

189. Install the fwd J + P sin G Follow-up Head while it is in its synchronized position. This position occurs when both the two front rollers (high speed) and the single roller (low speed) are on the synchronized segment which is marked with a white "O." As a check on the values of G – Br and I, vary Range and Target Speed, whereupon no motion of the Follow-up Head should appear.

190. Set Relative Target Bearing to 180 degrees. Leave Own Course set on zero degrees and Target Course set on 180 degrees.

191. Turn the aft G – Br Follow-up Motor until the aft Gyro Angle Order Dials read 180 degrees. The aft G – Br Stop is now on zero degrees, while the aft Cam Unit Gyro Angle input is in its 180 degrees position.

192. Check to see that Range is set at 8000 yards.

193. Set H in its maximum position by setting aft $\tan^{-1} T'a$ Stop at its maximum position.

194. Install the aft J + P sin G Follow-up Head while in its synchronized position. As a check on the values of G – Br and I, vary Range and Target Speed, whereupon no motion of the Follow-up Head should appear.

195. Set Target Speed to zero knots and Relative Target Bearing to 180 degrees on the Position Keeper. Leave Own Course set on zero degrees and Target Course set on 180 degrees.

196. Turn the aft G – Br Follow-up Motor until the aft Gyro Angle Order Dials read 180 degrees. The aft G – Br Stop is now on zero degrees.

197. Turn the Uy input gear on the front of the Angle Solver in a clockwise direction until it will turn no further. Uy is now on zero.

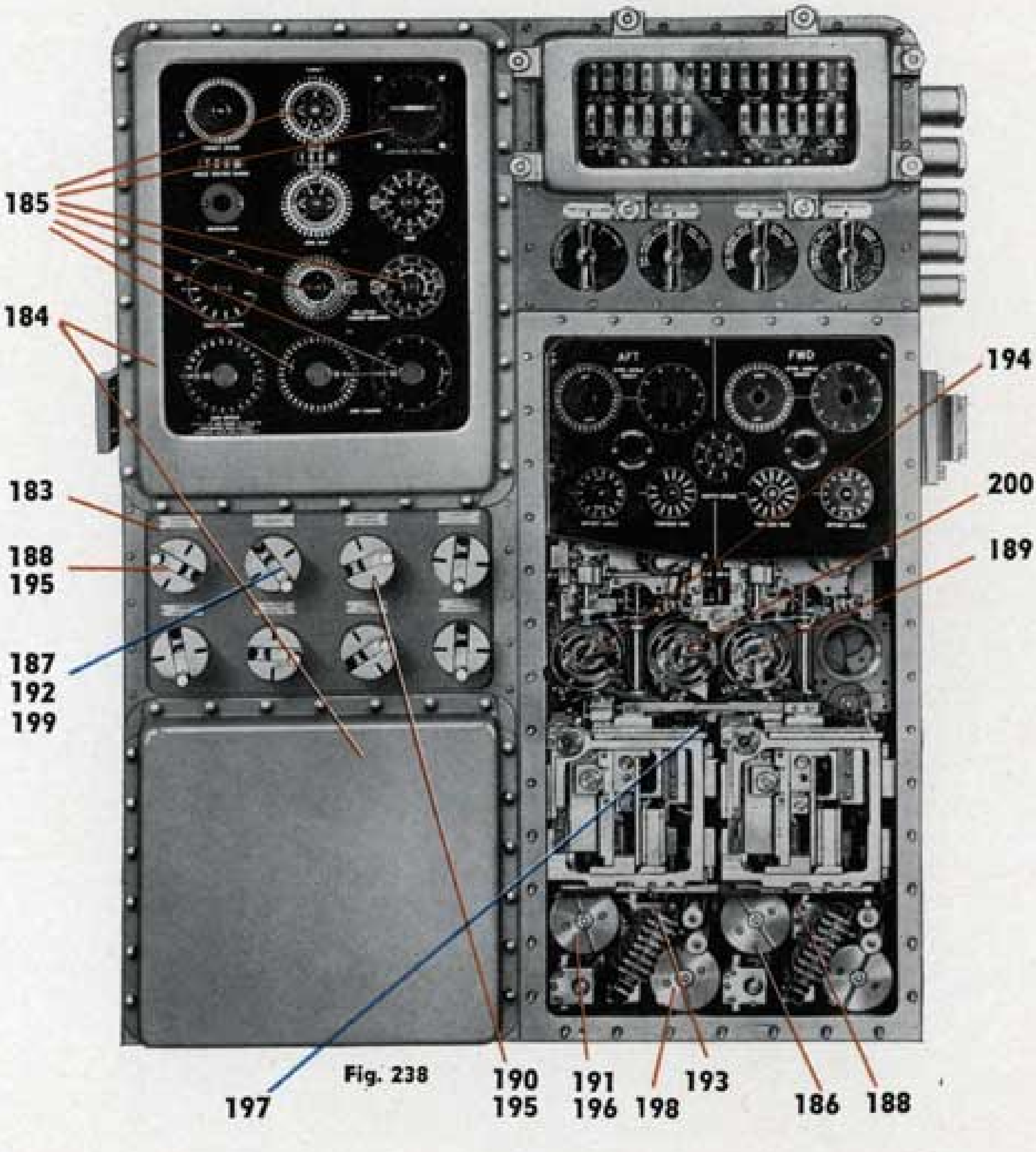


Fig. 238

198. Turn the aft tan $^{-1}$ T′a Follow-up Motor until the aft Torpedo Run Dial reads 300 yards.

199. Set the Range input on the Position Keeper until the value of Range equals 300 plus the Base Line value as set in on the Base Line Resolver in the aft Cam Unit. As this value is most probably still 100, as set at the installation of the Cam Unit, the Range should be set to 400 yards. Otherwise set the Range accordingly.

200. Install the aft Us+P cos G Follow-up Head while in its synchronized position.

201. Set Relative Target Bearing to zero degrees on the Position Keeper. Leave Own Course set on zero degrees and Target Course set on 180 degrees. Also, leave Target Speed set at zero knots and Uy set at zero.

202. Turn the fwd G − Br Follow-up Motor until the fwd Gyro Angle Order Dials read zero degrees. The fwd G − Br Stop is now on zero degrees.

203. Turn the fwd $\tan^{-1} T'a$ Follow-up Motor until the fwd Torpedo Run Dial reads 300 yards.

204. Set the Range input on the Position Keeper until the value of Range equals 300 plus the Base Line value as set in on the Base Line Resolver on the fwd Cam Unit.

205. Install the fwd $Us + P \cos G$ Follow-up Head while it is synchronized.

206. Temporarily connect an A.C. supply to A.C. and A.C.C. on the terminal block in the electrical compartment of the Angle Solver. Check and adjust the fwd $J + P \sin G$ Follow-up Head.

207. Set Turning Radius, Z, at 400 yards and Reach, M, at 200 yards by sliding the Z and M carriages to the left until they hit their stops. $Z_R - Z_L$ and $M_R - M_L$ must be zero when these settings are made. Clamp the carriages in this position.

208. Set Uy at zero by turning the Uy input gear clockwise until the zero stop is hit.

209. Set Base Line at 100 yards as in steps 130 to 132.

210. Make the following settings in the Position Keeper: $Co = 0°$ $S = 10$ knots $R = 3173$ yards $C = 0°$ $S'z = 60$ knots $Br = 88°12'$

211. Turn the power switch to the "Position Keeper and Angle Solver Test" position. The fwd Gyro Angle Order should be 90°.

212. By gently attempting to turn the fwd G − Br Follow-up Motor (which is energized and settled) first in one direction and then in the other, and by reading the fwd Gyro Angle Order Dials each time, it can be determined whether or not the fwd $J + P \sin G$ Follow-up Head is properly centered. If not, this condition can be corrected by slightly adjusting the trolley in the proper direction, using a follow-up head wrench to loosen and tighten the securing nut. Under no circumstances should any strain be imposed upon this member as damage might result to the rails or gearing if unduly strained. Hold the trolley by hand while adjusting the nut, otherwise the turning of the wrench will turn the trolley, which is definitely undesirable. The proper amount of backlash, as read on the high speed Gyro Angle Order Dial, is from $\pm 5'$ to $\pm 7'$. Turn the power switch to "Off."

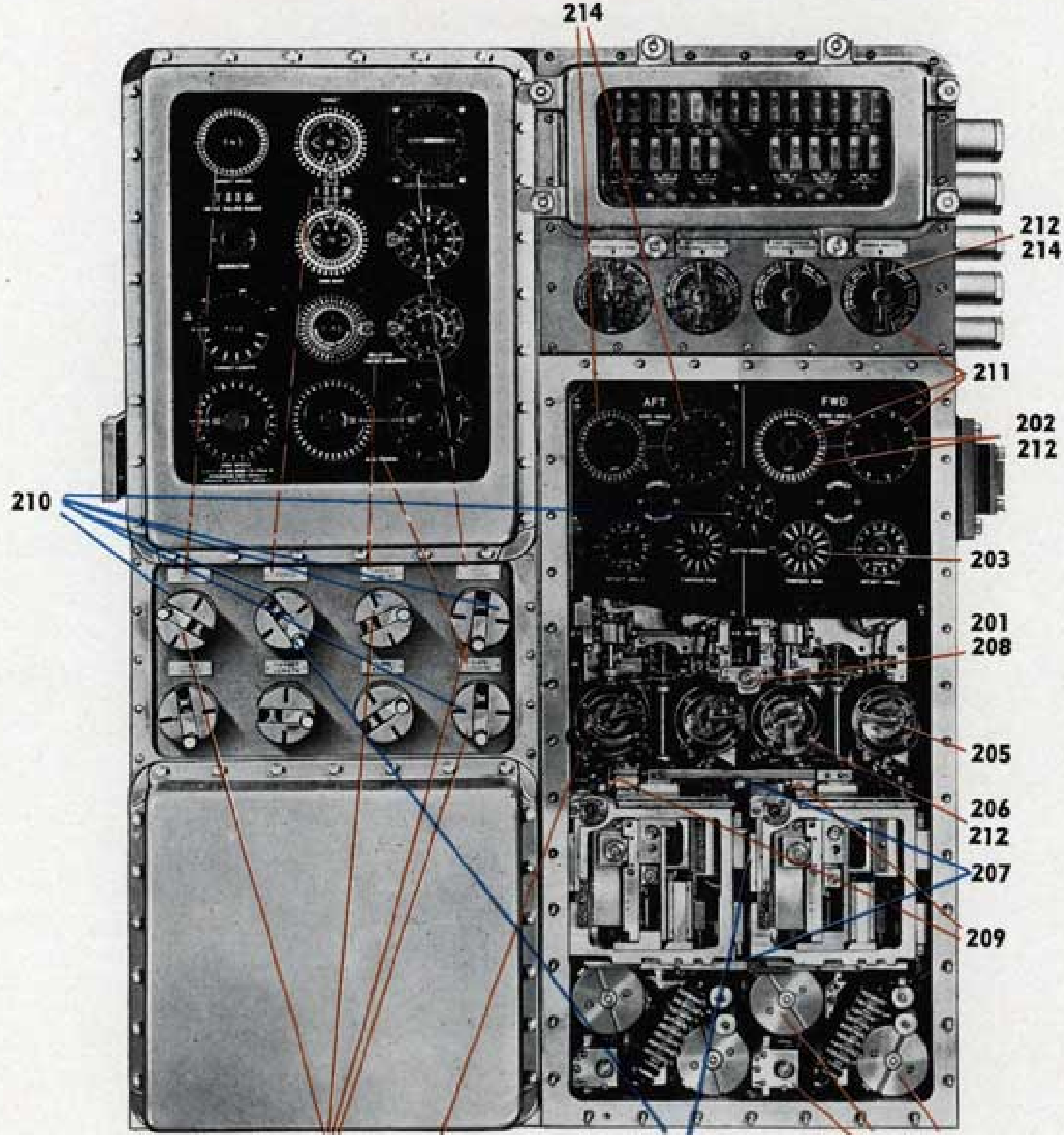


Fig. 239

213. To check the aft J+P sin G Follow-up Head, set values in the instrument as in steps 206 through 209 with these exceptions: set

C=180° Br=268°12'

214. Turn the power switch to the "Position Keeper and Angle Solver Test" position. The aft Gyro Angle Order should be 270°.

215. The method of checking and adjusting the aft $J+P\sin G$ Follow-up Head, and the allowable error, are the same as for the fwd head.

216. Leaving the values of Z, M, Uy and P set as in steps 206 through 208, make the following settings in the Position Keeper:

Co=0°	S=40 knots	R=1568 yards
C =150°	S'z=40 "	Br=2°27'

217. Turn the power switch to the "Position Keeper and Angle Solver Test" position. The fwd Gyro Angle Order should be 90°.

218. After the problem has been solved, the centering of the inner member of the $Us+P\cos G$ Follow-up Head must be checked, and adjusted if necessary. By gently turning the fwd $G-Br$ and $\tan^{-1}T'a$ Follow-up Motors first in one direction and then in the other, and by reading the fwd Gyro Angle Order Dials each time, it can be determined whether or not the trolley is properly set. These readings (minimum and maximum) should be centered about the theoretical correct solution. If not, the trolley must be reset.

219. Disconnect the armature leads of the fwd $\tan^{-1}T'a$ Follow-up Motor at the terminal block.

220. Move the fwd $\tan^{-1}T'a$ Follow-up Motor by hand until the readings (obtained by turning the fwd $G-Br$ Follow-up Motor first in one direction and then in the other) are centered about the theoretical correct solution.

221. When the spread has been properly set, loosen the trolley of the fwd $Us+P\cos G$ Head (which is no longer on its zero island) and bring it back onto its zero island, tightening it in this position.

222. Reconnect the armature leads of the fwd $\tan^{-1}T'a$ Follow-up Motor and again check the problem as was done at first, with both Follow-up Motors energized. The spread should now be equally spaced about the theoretical correct solution.

223. To check the aft $Us+P\cos G$ Follow-up Head proceed as in steps 215 through 221.

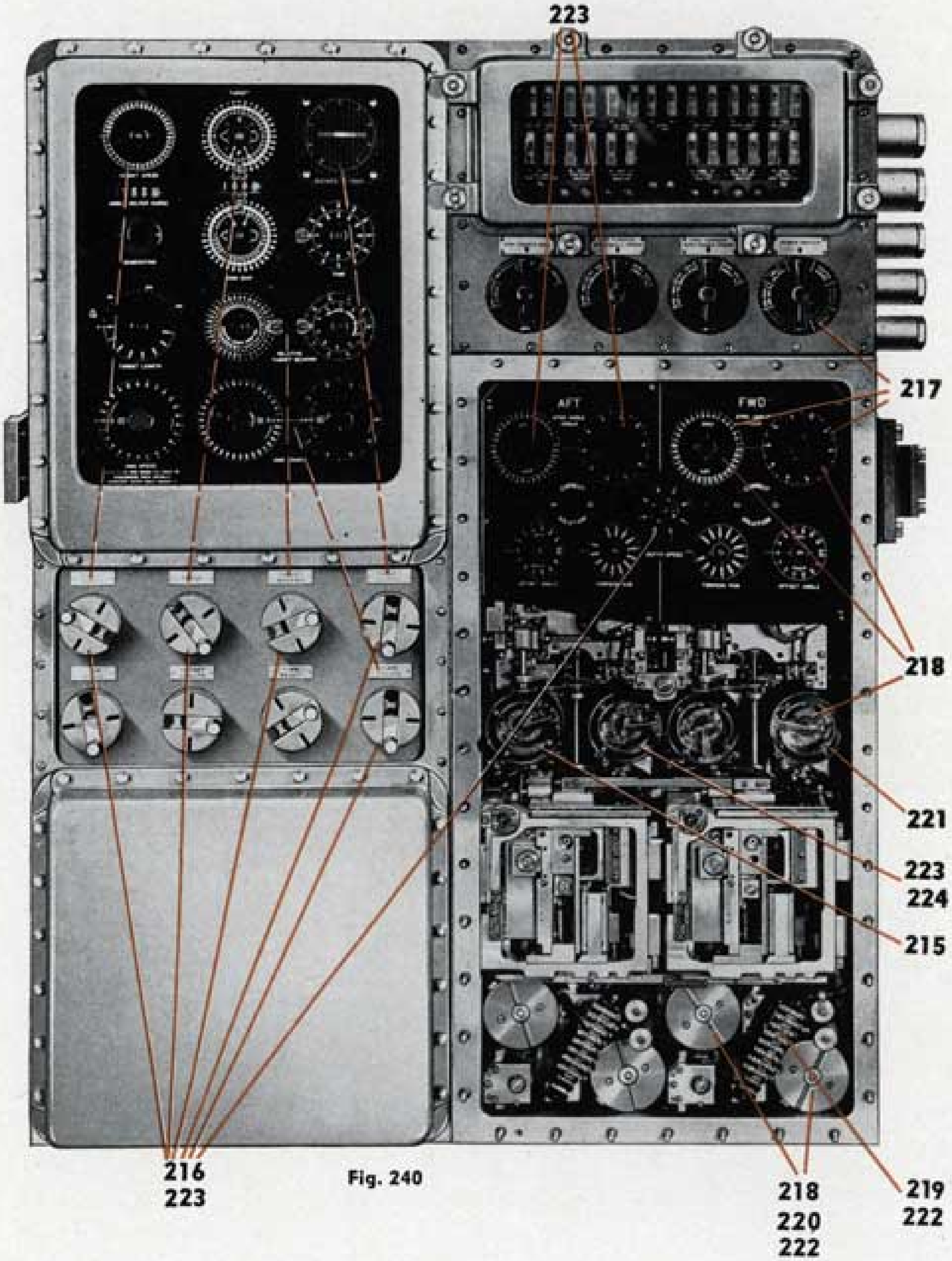


Fig. 240

with these exceptions: set C=330° and Br=182°37'. The aft Gyro Angle Order should be 270°.

224. Adjust the inner member of the head in the same manner that was used for the fwd head.

225. After all adjustments are made, remove the clamps from the Z and M inputs on the Cam Units.

226. Disconnect the A.C. supply from the terminal block.

227. Set the Tube Base Line in both the fwd and aft Cam Units to agree with the ship on which the Computer is installed.

228. Set $Z_R - Z_L$ and $M_R - M_L$ to agree with the Torpedoes being used.

229. Turn the Relative Target Bearing crank in the Position Keeper until Relative Target Bearing is on zero degrees. Set fwd and aft Offset Angles at zero.

230. Turn both G − Br Follow-up Motors and their Stops until all of the Gyro Angle Order Dials read zero degrees.

231. Set the aft low speed Gyro Angle Order Synchro first. Connect the Synchro electrically to a standard Synchro Motor whose dial has been set to read zero degrees when the motor is on electrical zero.

232. Using a synchro wrench, loosen the nut of the aft low speed Dial and turn the rotor within the dial hub (the dial hub remaining at zero) until the standard motor reads 180 degrees.

233. Tighten the nut and disconnect the Synchros.

234. Connect the fwd low speed Gyro Angle Order Synchro to the standard motor.

235. Loosen the nut of its dial and turn the rotor within the dial hub until the standard motor reads zero degrees.

236. Tighten the nut and disconnect the Synchros.

237. Remove the dial plate.

238. Connect the aft high speed Gyro Angle Order Synchro electrically to the standard motor.

239. Loosen the clamps of the generator.

240. If the standard motor is no more than 30 degrees off in either direction from zero, shift the Synchro Generator in the chassis (the gear, rotor and dial all remaining stationary) until the motor reads zero degrees.

241. Clamp the Synchro and disconnect it from the standard motor.

242. If the generator requires more turning than is practical because of the limitations of its leads, it will be necessary to loosen the clamps a sufficient amount to allow the generator gear to be unmeshed from its diving gear.

243. Turn the rotor (with gear and dial) until the motor dial is very close to zero degrees and remesh the gear.

244. Shift the generator until the motor dial reads exactly zero degrees, and tighten the clamps.

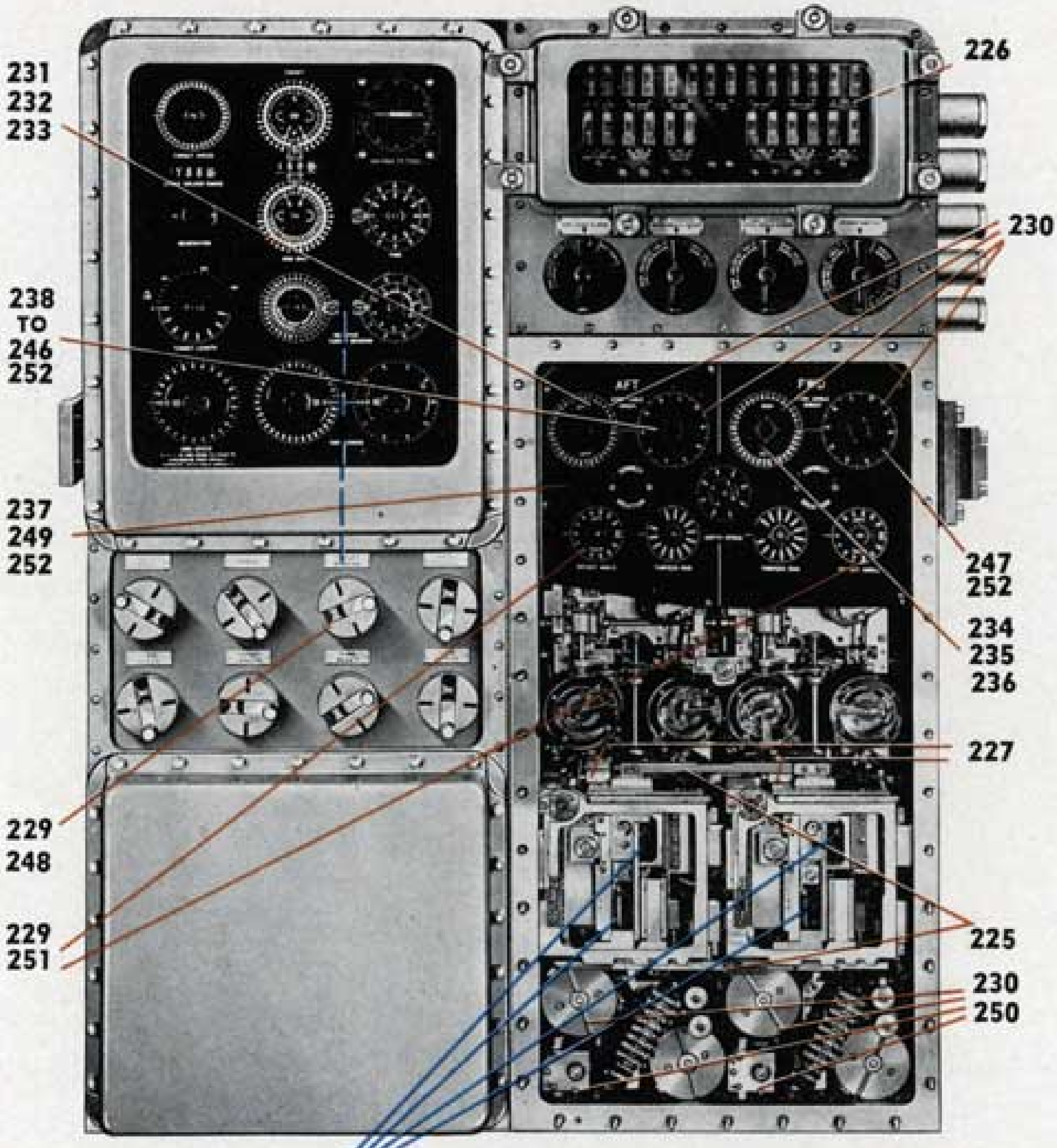


Fig. 241

245. Disconnect the Synchros.

246. Using the synchro wrench, adjust the Dial to read exactly zero degrees.

247. Repeat steps 238 to 246 for the fwd high speed Gyro Angle Order Synchro.

248. Set the Relative Target Bearing on zero degrees.

249. Replace dial plate.

250. Turn the fwd and aft G—Br Follow-up Motors and Stops until all of the Gyro Angle Order Dials read zero degrees.

251. Check that the Offset Angle Dials are on zero degrees.

252. Remove the dial plate and the fwd and aft one speed Gyro Angle Order Dials to provide access to the cams behind the dials.

253. Adjust the aft cam so that the cam disc lobes are superimposed, the assembly now having a lobe no wider than that of one of the discs.

254. Position the center of the lobe (leaving the dials on zero) on the contact roller. This sets the cams approximately for a spread of ± 150 degrees. The spacing is done by loosening three screws which can be seen to clamp the cam discs to the gear hob. The cam now has been set so that clockwise turning of the Relative Target Bearing crank will lift the roller and operate the switch plunger when the Relative Target Bearing Dial reaches 330 degrees (increasing from lower values), and further, so that counterclockwise turning of the crank will actuate the roller and switch when the dial reaches 30 degrees (decreasing from higher values).

255. If the cams need further slight adjustment in order to satisfy the above conditions (which must be met as accurately as possible), again loosen the three clamping screws and reset the cam discs, changing the overall width of the lobe slightly, if necessary.

256. Leaving G—Br on zero degrees, turn Relative Target Bearing to read 180 degrees. The Gyro Angle Order Dials are now on 180 degrees.

257. Set the fwd cam in a manner similar to that used for the aft cam, setting the Cam disc lobes together.

258. Centralize the lobe on the contact roller as before.

259. Check fwd cam by turning the Relative Target Bearing crank in a clockwise direction. When the dial reaches 150 degrees (increasing from lower values), the switch should operate. When the crank is turned in a counterclockwise direction the switch should operate when the dial reaches 210 degrees (decreasing from higher values).

260. If slight adjustment is necessary, loosen the three clamping screws and reset the cams.

261. Replace the dials and the dial plate. Set each correct solution light switch behind the Torpedo Run Dials in the following manner.

262. Turn the $\tan^{-1}T'a$ Follow-up Motor and Stop until the Torpedo Run Dial reads 300 yards.

263. Remove the dial plate and the dial. These must be removed and replaced several times while reading the dial and setting the cam. Care must be taken to replace dial in the proper position.

264. The cam will be seen to be similar to the cams previously set, and also is secured by three clamping screws.

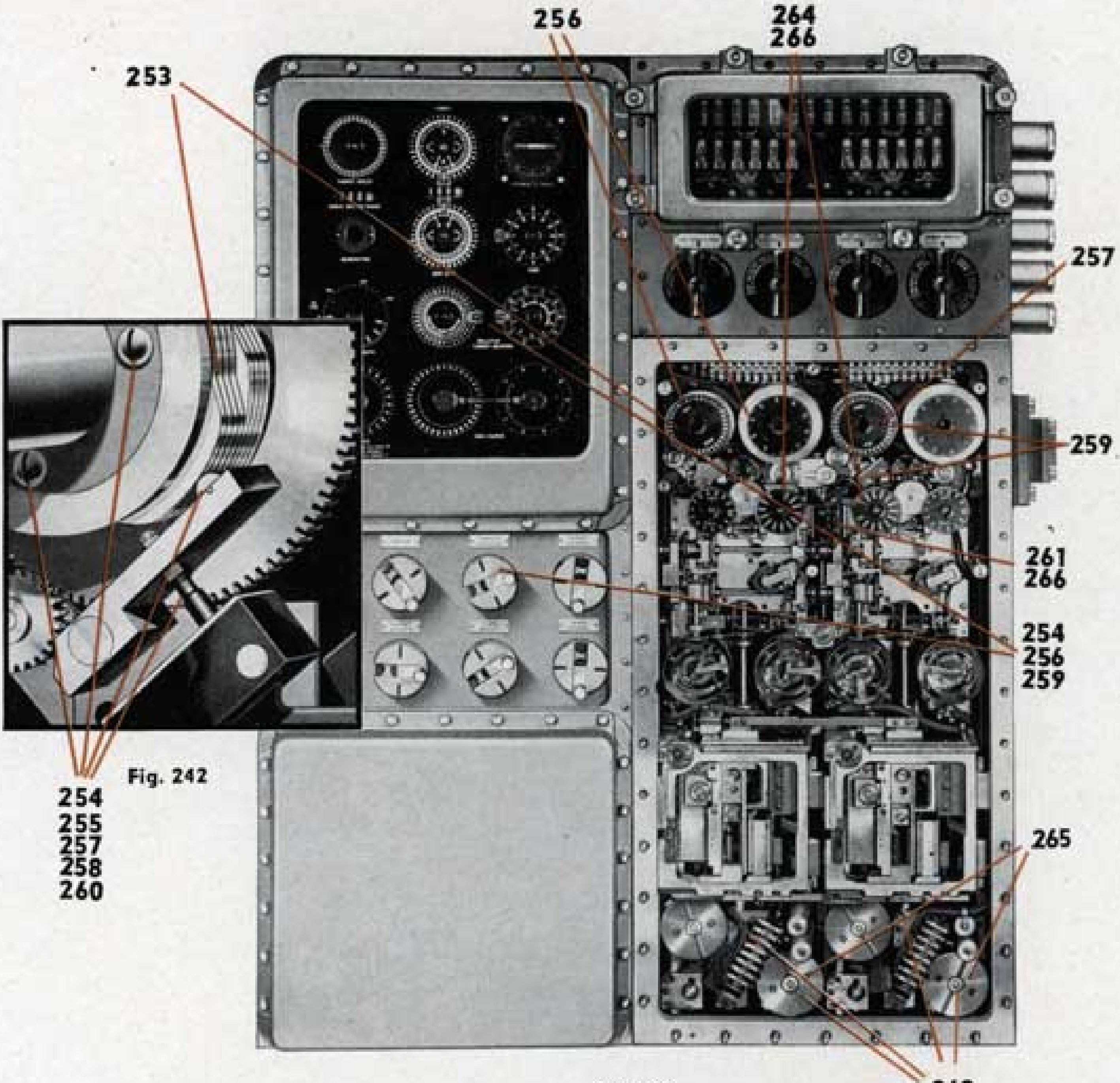


Fig. 242

Fig. 243

Fan out the discs of this cam so that the 300 yard end of the cam just actuates the switch (pushes in the plunger and clicks) when at 300 yards, or a few yards before reaching 300, when the dial is turned in a decreasing (counterclockwise) direction. Never allow it to actuate after going below 300 yards. The adjustment can be made at the adjusting screw on the roller arm as well as at the cam itself.

265. Turn the $\tan^{-1}$ T'a Follow-up Motor until the dial reads 4500 yards. Set S'z to maximum position.

266. Adjust the 4500 yard end of the cam (leaving the 300 yard end untouched) until it is set to actuate the switch when at 4500 yards, or a few yards before reaching 4500, when the dial is turned in an increasing (clockwise) direction. Never allow it to actuate the switch after going above 4500 yards.

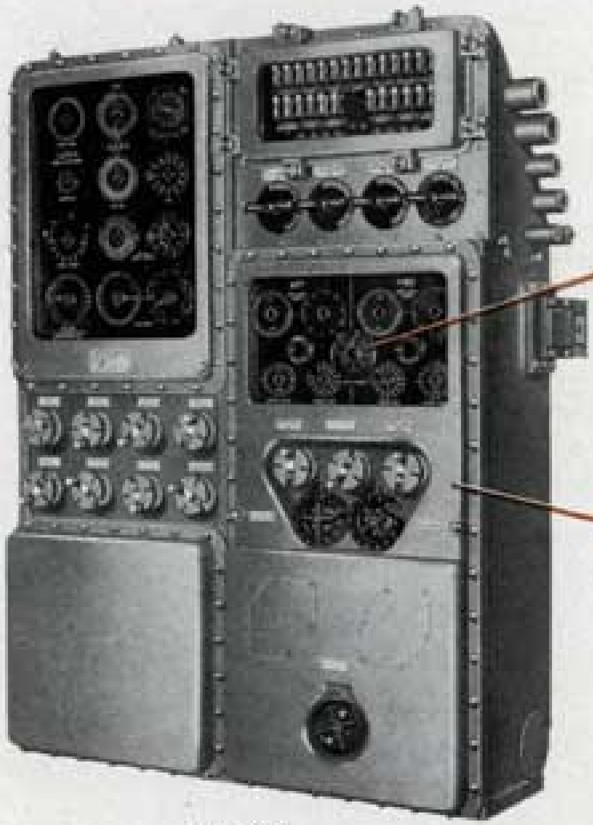


Fig. 244

267. Secure the dial plates and install the transparent Depth Set Dial. This dial should be replaced so that the engraved line, which is about 1/4 inch counter-clockwise from the 50 foot mark of the 15LO marking, is directly over the 25 knot engraving of the S'z Dial. On instruments that do not have the 15LO marking, the index mark may be recognized as a straight line with a small circle in the middle.

268. Replace the front cover of the Angle Solver. Use the following procedure for replacing the Angle Solver cover.

When replacing this cover it is necessary to set three input shafts on the front of the chassis. (1) Turn the Uy input gear clockwise as far as it will go. (2) Move the Z carriages and M carriages to the right as far as they will go. (3) Now set the Uy, Z, and M Dials on the front of the cover to read as follows:

Set Uy at 0

When Z_R is greater than Z_L, set Z at $+75+(Z_R-Z_L)$.

When Z_L is equal to, or greater than Z_R, set Z at $+75$.

When M_R is greater than M_L, set M at $-50+(M_R-M_L)$.

When M_L is equal to, or greater than M_R, set M at -50.

The values of Z_R, Z_L, M_R, and M_L are supplied with the torpedo.

The cover may now be installed, being careful not to move any of the values set above, when meshing their respective gears. The instrument is now completely reassembled and can be replaced upon its mountings and secured in place, after which all wiring should be connected to the terminal blocks in the electrical compartment of the Angle Solver.

TESTS

Tests should be run on the Data Computer periodically, both to exercise the instrument and to instruct the personnel in its operation.

SECTION 6

POSITION KEEPER TESTS

In order to test the generating elements of the Position Keeper for given starting values of Own Speed, Own Course, Target Speed, Target Course, Range and Target Bearing, as in the problems on Pages 220 to 225, proceed as follows:

1. Throw the power supply switch to the "Position Keeper" position with the Time Motor off for "Test Purpose Only" (red portion of dial).

2. Set in given values of Own Speed, Own Course, Target Speed, Target Course, Range and Target Bearing.

3. Set the Time Dial to zero.

4. Throw the power supply switch to the "Position Keeper" position (white portion of the dial). This starts the generation of the problem.

5. Continue generation and take readings of Range and Relative Target Bearing at the marked time intervals as required by the problem, until all readings are taken.

6. Repeat the above steps for all of the problems indicated on the Position Keeper Tests. In order to take the readings of problem #13, it will be necessary to use a camera and photograph the dials, thus insuring the simultaneous reading of every dial.

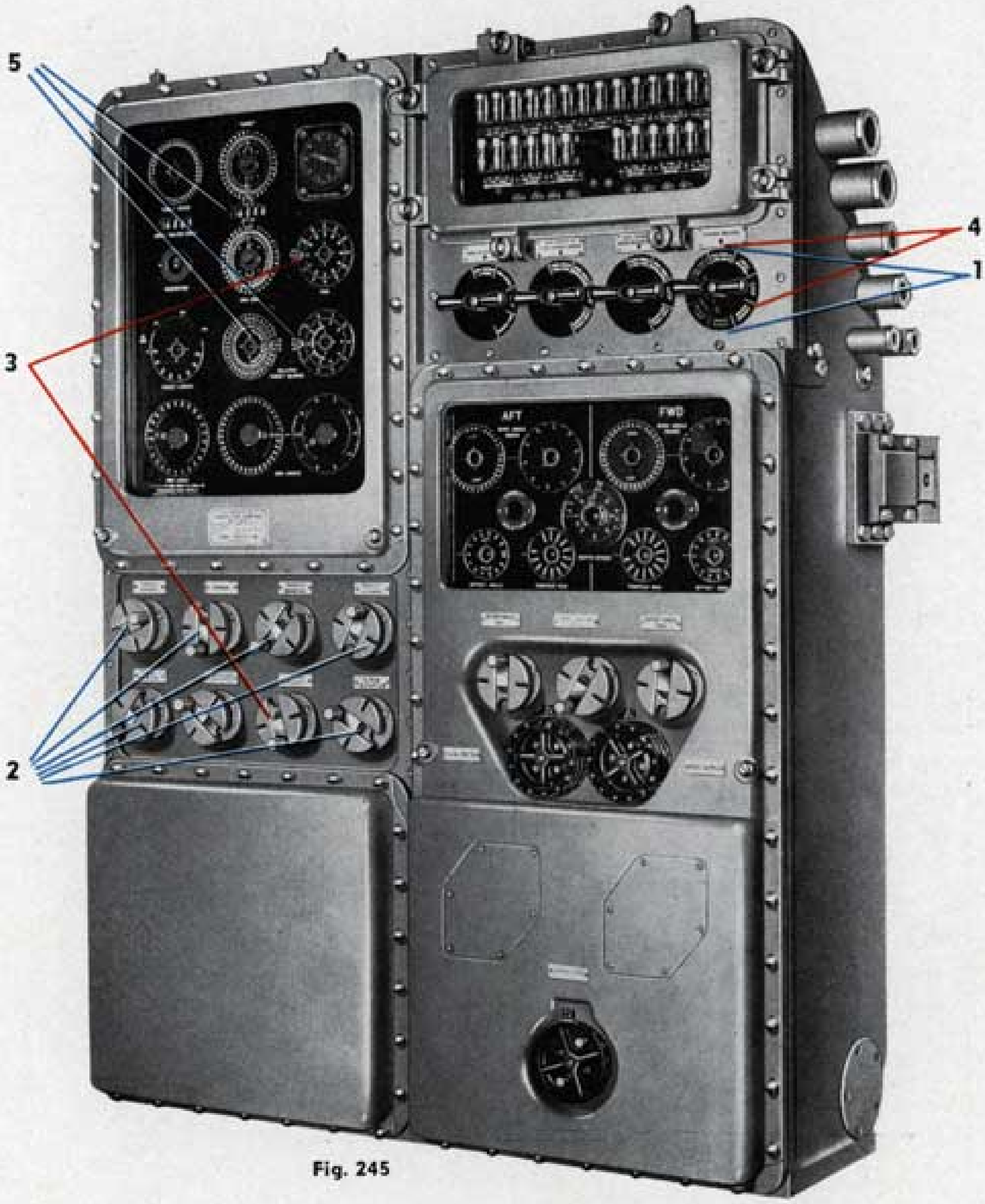


Fig. 245

For MK. 3, Mods. 5 to 12, Inc.

PROBLEM 1

Target Speed S=5 Knots — Own Speed So=2 Knots
Target Course C=35°0' — Own Course Co=210°0'
Target Bearing Br=20°0' — Range R=2500 Yds.

Time	TARGET BEARING								RANGE			
	Theor.		Observed		Err.	Err.	All.	(%)	Theor.	Obsvd.	Err.	Err.
Min.	Deg.	Min.	Deg.	Min.		Min.	Err.	Err.	Yards	Yards		Min.
0	20	0	—	—	—	—	—	—	2500	—	—	—
3	26	17					10		1831			
6	39	22					17		1209			
7	47	07					29		1026			
8	57	53					35		871			
9	72	34					40		757			
10	90	43					43		708			
11	109	27					44		735			
12	125	18					41		831			
13	137	11					37		977			
14	145	43					31		1152			
15	151	54					23		1347			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

PROBLEM 2

Target Speed S=10 Knots — Own Speed So=3 Knots
Target Course C=320°0' — Own Course Co=150°0'
Target Bearing Br=345°0' — Range R=4000 Yds.

Time	TARGET BEARING								RANGE			
	Theor.		Observed		Err.	Err.	All.	(%)	Theor.	Obsvd.	Err.	Err.
Min.	Deg.	Min.	Deg.	Min.		Min.	Err.	Err.	Yards	Yards		Min.
0	345	0	—	—	—	—	—	—	4000	—	—	—
3	341	27					10		2702			
6	331	31					13		1433			
7	322	53					24		1035			
8	304	41					38		688			
9	265	14					48		509			
10	223	17					49		654			
11	203	12					40		990			
12	193	51					26		1385			
13	188	43					14		1799			
14	185	32					10		2223			
15	183	22					10		2651			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

For Mk. 3, Mods. 5 to 12, Inc.

PROBLEM 3

Target Speed S=10 Knots — Own Speed So=5 Knots
Target Course C=120°0' — Own Course Co=270°0'
Target Bearing Br=25°0' — Range R=5000 Yds.

Time	TARGET BEARING								RANGE			
	Theor.		Observed		Err.	Err.	All.	(%)	Theor.	Obsvd.	Err.	Err.
Min.	Deg.	Min.	Deg.	Min.		Min.	Err.	Err.	Yards	Yards		Min.
0	25	0	—	—	—	—	—	—	5000	—	—	—
3	27	3					10		3534			
6	31	57					10		2078			
7	35	34					10		1600			
8	42	12					19		1134			
9	57	27					36		704			
10	101	03					50		432			
11	154	52					52		601			
12	175	05					41		1009			
13	183	13					24		1469			
14	187	26					12		1945			
15	189	59					10		2427			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

For MK. 3, Mods. 5 to 12, Inc.

PROBLEM 4

Target Speed S=15 Knots — Own Speed So=10 Knots
Target Course C=235°0' — Own Course Co=0°0'
Target Bearing Br=45°0' — Range R=8000 Yds.

Time	TARGET BEARING								RANGE			
	Theor.		Observed		Err.	Err.	All.	(%)	Theor.	Obsvd.	Err.	Err.
Min.	Deg.	Min.	Deg.	Min.		Min.	Err.	Err.	Yards	Yards		Min.
0	45	0	—	—	—	—	—	—	8000	—	—	—
3	49	28					10		5804			
6	59	13					10		3686			
7	65	26					10		3025			
8	74	55					10		2420			
9	89	58					10		1921			
10	112	37					10		1632			
11	139	01					10		1664			
12	160	15					10		2002			
13	174	04					10		2526			
14	182	48					10		3145			
15	188	35					10		3812			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

For Mk. 3, Mods. 5 to 12, Inc.

TESTS

PROBLEM 5

Target Speed S=20 Knots — Own Speed So=7 Knots
Target Course C=340°0′ — Own Course Co=240°0′
Target Bearing Br=310°0′ — Range R=8000 Yds.

Time Min.	TARGET BEARING								RANGE			
	Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err. Min.	All. Err.	(%) Err.	Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	310	0	—	—	—	—	—	—	8000	—	—	—
3	314	39					10		5808			
6	324	43					10		3699			
7	331	06					10		3045			
8	340	47					10		2449			
9	355	54					10		1963			
10	18	07					10		1688			
11	43	35					10		1727			
12	64	12					10		2061			
13	77	50					10		2579			
14	86	36					10		3192			
15	92	26					10		3855			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

PROBLEM 7

Target Speed S=25 Knots — Own Speed So=7 Knots
Target Course C=145°0′ — Own Course Co=120°0′
Target Bearing Br=210°0′ — Range R=6000 Yds.

Time Min.	TARGET BEARING								RANGE			
	Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err Min.	All. Err.	(%) Err.	Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	210	0	—	—	—	—	—	—	6000	—	—	—
3	208	08					10		4093			
6	202	59					10		2197			
7	198	34					10		1576			
8	188	32					22		976			
9	154	04					43		485			
10	80	44					51		576			
11	56	27					39		1115			
12	48	06					19		1723			
13	44	18					10		2347			
14	42	07					10		2977			
15	40	41					10		3610			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

For Mk. 3, Mods. 5 to 12, Inc.

PROBLEM 6

Target Speed S=20 Knots — Own Speed So=10 Knots
Target Course C=355°0′ — Own Course Co=60°0′
Target Bearing Br=75°0′ — Range R=6000 Yds.

Time Min.	TARGET BEARING								RANGE			
	Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err. Min.	All. Err.	(%) Err.	Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	75	0	—	—	—	—	—	—	6000	—	—	—
3	70	34					10		4198			
6	59	43					10		2457			
7	51	49					10		1920			
8	38	20					13		1447			
9	14	45					22		1119			
10	342	22					29		1081			
11	316	08					25		1356			
12	300	49					15		1807			
13	291	59					10		2334			
14	286	28					10		2895			
15	282	47					10		3475			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

PROBLEM 8

Target Speed S=25 Knots — Own Speed So=5 Knots
Target Course C=270°0′ — Own Course Co=300°0′
Target Bearing Br=135°0′ — Range R=6530 Yds.

Time Min.	TARGET BEARING								RANGE			
	Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err. Min.	All. Err.	(%) Err.	Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	135	0	—	—	—	—	—	—	6500	—	—	—
3	131	9					10		4421			
6	120	39					10		2396			
7	111	53					10		1768			
8	94	32					17		1222			
9	59	40					30		922			
10	19	59					33		1094			
11	358	15					20		1591			
12	347	40					10		2204			
13	341	48					10		2859			
14	338	08					10		3532			
15	335	40					10		4215			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

For Mk. 3, Mods. 5 to 12, Inc.

For Mk. 3, Mods. 5 to 12, Inc.

For Mk. 3, Mods. 5 to 12, Inc.

PROBLEM 9

Target Speed S=30 Knots — Own Speed So=15 Knots
Target Course C=15°0' — Own Course Co=30°0'
Target Bearing Br=140°0' — Range R=7000 Yds.

Time Min.	TARGET BEARING Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err. Min.	All. Err.	(%) Err.	RANGE Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	140	0	—	—	—	—	—	—	7000	—	—	—
3	136	45					10		5418			
6	130	51					10		3868			
7	127	41					10		3366			
8	123	26					10		2877			
9	117	31					10		2412			
10	108	51					10		1983			
11	95	58					10		1623			
12	77	21					14		1386			
13	54	34					19		1338			
14	33	33					17		1497			
15	18	12					11		1810			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

PROBLEM 11

Target Speed S=40 Knots — Own Speed So=15 Knots
Target Course C=335°0' — Own Course Co=330°0'
Target Bearing Br=195°0' — Range R=8000 Yds.

Time Min.	TARGET BEARING Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err. Min.	All. Err.	(%) Err.	RANGE Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	195	0	—	—	—	—	—	—	8000	—	—	—
3	198	15					10		5485			
6	206	53					10		3017			
7	213	56					10		2232			
8	228	06					11		1516			
9	260	16					23		1026			
10	306	43					30		1114			
11	332	45					19		1693			
12	344	20					10		2435			
13	350	23					10		3229			
14	354	01					10		4045			
15	356	25					10		4872			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

For Mk. 3, Mods. 5 to 9, 11 and 12, Only

PROBLEM 10

Target Speed S=30 Knots — Own Speed So=20 Knots
Target Course C=200°0' — Own Course Co=180°0'
Target Bearing Br=220°0' — Range R=4500 Yds.

Time Min.	TARGET BEARING Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err Min.	All. Err.	(%) Err.	RANGE Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	220	0	—	—	—	—	—	—	4500	—	—	—
3	215	18					10		3207			
6	204	28					10		1963			
7	197	10					10		1581			
8	185	33					17		1240			
9	166	40					29		984			
10	139	53					36		890			
11	113	42					35		1005			
12	95	44					28		1273			
13	84	42					16		1620			
14	77	44					10		2006			
15	73	03					10		2411			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

PROBLEM 12

Target Speed S=40 Knots — Own Speed So=22 Knots
Target Course C=80°0' — Own Course Co=90°0'
Target Bearing Br=150°0' — Range R=6000 Yds.

Time Min.	TARGET BEARING Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err. Min.	All. Err.	(%) Err.	RANGE Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	150	0	—	—	—	—	—	—	6000	—	—	—
3	146	15					10		4131			
6	136	23					10		2308			
7	128	36					10		1737			
8	113	50					15		1228			
9	84	08					31		893			
10	43	55					37		942			
11	18	19					27		1334			
12	5	41					15		1863			
13	358	49					10		2442			
14	354	38					10		3042			
15	351	50					10		3653			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

For Mk. 3, Mods. 5 to 12, Inc.

PROBLEM 13

MAXIMUM RATE PROBLEM

Target Speed S=40 Knots	Own Speed So=10 Knots
Target Course C=270°0'	Own Course Co=90°0'
Target Bearing Br=2°20'	Range R=8000 Yds

	GENERATED VALUES											
	TARGET BEARING								RANGE			
Time	Theor.		Observed		Err.	Err Min.	All. Err.	(%) Err.	Theor. Yards	Obsvd. Yards	Err.	Err. Min.
Min.	Deg.	Min.	Deg.	Min.								
0	2	20	—	—	—	—	—	—	8000	—	—	—
0 15	2	28					10		7578			
0 30	2	36					10		7156			
0 45	2	46					10		6735			
1	2	57					10		6313			
1 15	3	10					10		5891			
1 30	3	25					10		5470			
1 45	3	42					10		5048			
2	4	02					10		4627			
2 15	4	26					10		4206			
2 30	4	55					10		3785			
2 45	5	33					10		3365			
3	6	21					10		2945			
3 15	7	25					10		2525			
3 30	8	53					10		2107			
3 45	11	06					10		1691			
4	14	45					11.5		1280			
4 15	21	47					17		878			
4 30	39	39					26		510			
4 45	95	07					35		327			
5	144	11					48		557			
5 15	159	33					48		932			
5 30	165	53					44		1336			
5 45	169	16					35		1749			
6	171	21					21		2165			
6 15	172	45					17		2583			
6 30	173	46					11		3003			
6 45	174	32					10		3423			
7	175	08					10		3843			
7 15	175	37					10		4264			
7 30	176	01					10		4685			
7 45	176	21					10		5107			
8	176	37					10		5528			
8 15	176	52					10		5950			
8 30	177	04					10		6371			
8 45	177	15					10		6793			
9	177	25					10		7215			
							Sum				Sum	
							Ave. (%) Err.				Ave. Err./Min.	
							Allow. (%) Err.	100			Allow. Err/Min.	
							Max. (%) Err.				Max. Err./Min.	
							Max. All. (%) Err.	300			Max. All. Err./M.	

For Mk. 3, Mod. 10, Only

PROBLEM 14

Target Speed S=30 Knots
Target Course C=205°0′
Target Bearing Br=220°0′

Own Speed So=18 Knots
Own Course Co=180°0′
Range R=4500 Yds.

	TARGET BEARING								RANGE			
Time Min.	Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err. Min.	All. Err.	(%) Err.	Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	220	0	—	—	—	—	—	—	4500	—	—	—
3	212	35					10		2986			
6	191	31					10		1618			
7	175	17					10		1280			
8	151	2					10		1102			
9	124	12					10		1163			
10	103	52					10		1432			
11	91	2					15		1819			
12	82	58					26		2264			
13	77	36					31		2739			
14	73	51					20		3231			
15	71	6					11		3733			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

For Mk. 3, Mods. 10 and 11, Only

PROBLEM 15

Target Speed S=40 Knots
Target Course C=80°0′
Target Bearing Br=150°0′

Own Speed So=18 Knots
Own Course Co=90°0′
Range R=6000 Yds.

	TARGET BEARING								RANGE			
Time Min.	Theor. Deg.	Theor. Min.	Observed Deg.	Observed Min.	Err.	Err. Min.	All Err.	(%) Err.	Theor. Yards	Obsvd. Yards	Err.	Err. Min.
0	150	0	—	—	—	—	—	—	6000	—	—	—
3	142	50					10		3801			
6	118	24					10		1810			
7	95	48					10		1365			
8	62	30					10		1266			
9	34	12					10		1580			
10	17	51					10		2135			
11	8	39					12		2787			
12	3	2					19		3485			
13	359	19					15		4208			
14	356	41					10		4923			
15	354	44					10		5660			
				Allow.	100	Average			Allow.	10	Average	
				Max. All.	300	Maximum			Max. All.	30	Maximum	

POSITION KEEPER NOTES (Explanation of Column Heads)

1. "ERR" (The error) The difference between the value in the "Theoretical" and "Observed" columns.

2. "ERR MIN" (The error per minute) The value in the "ERR" column for a particular time minus the value in this column for the previous time interval divided by the elapsed time.

3. "ALL ERR" (The allowable error) The value in generated bearing, which is determined as follows:

For ranges of 300 yds. .... 60 minutes of arc per minute of time.
For ranges of 1600 yds. and over .... 10 minutes of arc per minute of time.
For ranges between 300 and 1600 yds. . . . the allowable error is computed from the following equation:
ALL ERR=1600−R/1600×50+10
Where R=Range in Yards

4. "% ERR" (The percent error) The value in the "ERR MIN" column divided by the value in the "ALL ERR" column multiplied by 100.

ANGLE SOLVER TESTS

1. Put the power switch in the "Angle Solver" position.

2. Set in values of Range, Target Bearing, Target Course and Target Speed as given in the problems on Pages 226 to 232.

3. Set in correction values as indicated.

4. For each of the above settings record values of Gyro Angle, Torpedo Run and Track Angle.

Fig. 246

For Mk. 3, Mods. 5 to 12, Inc.
Fwd Angle Solver Problems for use on SS-206 to SS-544, Inc.

P=98 FT. Z=200 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	M Reach Yards	Observed Deg.	Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
1	1963	345	15	150	40	40	0	-50	—	—	0	—	86	—	1000	—	—	30S	—	—	1.5°	—
2	615	358	58	120	30	55	25	-25			30		172		500			90S			3.0°	
3	4109	40	59	90	20	50	50	0			60		15		6000			150S			0.5°	
4	2873	84	51	60	0	25	75	25			90		29		3000			150P			0.5°	
5	3879	112	44	10	10	35	100	50			100		21		4000			90P			0.5°	
6	4638	108	37	320	5	45	125	75			110		19		4500			30P			0.5°	
7	1967	227	35	10	40	50	150	100			250		57		1500			60S			1.0°	
8	1277	234	24	320	30	60	175	125			260		43		2000			120S			0.5°	
9	3550	256	10	30	20	45	200	150			270		29		3000			60S			0.5°	
10	3570	319	33	240	10	40	225	175			300		21		4000			120P			0.5°	
11	3870	340	11	210	5	30	250	200			330		25		3500			60P			0.5°	

Gyro Angle		Torpedo Run		Track Angle	
Sum		Sum		Sum	
Ave. % Error		Ave. Error		Ave. % Error	
Allow. % Error	100	Allow. Error	50	Allow. % Error	100
Max. % Error		Max. Error		Max. % Error	
Max. All. % Error	300	Max. All. Error	150	Max. All. % Error	300

P=98 FT. M=50 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	Z Radius of Turn Yards	Observed Deg.	Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
12	1963	345	15	150	40	40	0	75	—	—	0	—	86	—	1000	—	—	30S	—	—	1.5°	—
13	621	356	38	120	30	55	25	105			30		172		500			90S			3.0°	
14	4099	40	45	90	20	50	50	140			60		15		6000			150S			0.5°	
15	2864	84	56	60	0	25	75	170			90		29		3000			150P			0.5°	
16	3874	112	40	10	10	35	100	205			100		21		4000			90P			0.5°	
17	4638	108	17	320	5	45	125	235			110		19		4500			30P			0.5°	
18	1950	228	51	10	40	50	150	270			250		57		1500			60S			1.0°	
19	1270	236	24	320	30	60	175	300			260		43		2000			120S			0.5°	
20	3564	256	48	30	20	45	200	335			270		29		3000			60S			0.5°	
21	3592	318	59	240	10	40	225	365			300		21		4000			120P			0.5°	
22	3877	339	26	210	5	30	250	400			330		25		3500			60P			0.5°	

Gyro Angle		Torpedo Run		Track Angle	
Sum		Sum		Sum	
Ave. % Error		Ave. Error		Ave. % Error	
Allow. % Error	100	Allow. Error	50	Allow. % Error	100
Max. % Error		Max. Error		Max. % Error	
Max. All. % Error	300	Max. All. Error	150	Max. All. % Error	300

MK. 3 MOD. 5 MK. 14 TORPEDO BASELINE=98 FEET OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Min.	C Target Course Deg.	S Target Speed Knots	Sz Stand. Speed Knots	Depth Set Feet	Uy Yards	Observed Deg.	Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
45	1842	346	17	150	40	47.288	30	0	—	—	0	—	86	—	1000	—	—	30S	—	—	1.5°	—
46	657	351	42	120	30	47.288	15	25			30		172		500			90S			3.0°	
47	2011	35	36	90	20	47.288	15	50			60		29		3000			150S			0.5°	
48	1845	80	28	60	0	47.288	50	75			90		43		2000			150P			0.5°	
49	3806	108	40	10	10	47.288	40	100			100		21		4000			90P			0.5°	
50	4630	108	26	320	5	47.288	20	125			110		19		4500			30P			0.5°	
51	1329	227	41	10	40	47.288	15	150			250		86		1000			60S			1.5°	
52	4483	221	42	320	30	47.288	10	175			260		16		5500			120S			0.5°	
53	3650	255	30	30	20	47.288	20	200			270		29		3000			60S			0.5°	
54	3630	315	18	240	10	47.288	30	225			300		21		4000			120P			0.5°	
55	4812	336	12	210	5	47.288	40	250			330		19		4500			60P			0.5°	

Z_R=215 YDS. M_R=57.93 YDS.
Z_L=206 YDS. M_L=32.46 YDS.

Gyro Angle		Torpedo Run		Track Angle	
Sum		Sum		Sum	
Ave. % Error		Ave. Error		Ave. % Error	
Allow. % Error	100	Allow. Error	50	Allow. % Error	100
Max. % Error		Max. Error		Max. % Error	
Max. All. % Error	300	Max. All. Error	150	Max. All. % Error	300

Aft Angle Solver Problems for use on SS-206 to SS-544, Inc.

P=179 FT. Z=200 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	M Reach Yards	Gyro Angle Observed Deg.	Observed Min.	Comp. Deg.	Error Min.	Allow. Error Min.	% Error	Torpedo Run Comp. Yards	Obsvd. Yards	Error Yards	Track Angle Comp. Deg.	Obsvd. Deg.	Error Deg.	Allow. Error	% Error
23	1024	165	52	330	30	30	0	-50	—	—	180	—	172	—	500	—	—	30S	—	—	3.0°	—
24	4125	205	54	240	5	45	25	-25			210		19		4500			150S			0.5°	
25	2549	260	47	180	20	50	50	0			240		29		3000			120P			0.5°	
26	5688	233	25	330	30	55	75	25			270		15		6500			120S			0.5°	
27	1565	283	34	130	40	50	100	50			280		86		1000			30P			1.5°	
28	1729	294	31	200	10	40	125	75			290		43		2000			90P			0.5°	
29	4196	63	26	190	10	40	150	100			70		21		4000			60S			0.5°	
30	734	99	48	170	5	35	175	125			80		86		1000			90S			1.5°	
31	2555	119	27	330	20	45	200	150			90		43		2000			60P			0.5°	
32	5598	158	5	30	40	60	225	175			120		19		4500			90P			0.5°	
33	2525	153	33	120	0	25	250	200			150		34		2500			150P			0.5°	
											Sum				Sum				Sum			
											Ave. % Error				Ave. Error				Ave. % Error			
											Allow. % Error			100	Allow. Error		50		Allow. % Error			100
											Max. % Error				Max. Error				Max. % Error			
											Max. All. % Error			300	Max. All. Error		150		Max. All. % Error			300

P=179 FT. M=50 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	Z Radius of Turn Yards	Gyro Angle Observed Deg.	Observed Min.	Comp. Deg.	Error Min.	Allow. Error Min.	% Error	Torpedo Run Comp. Yards	Obsvd. Yards	Error Yards	Track Angle Comp. Deg.	Obsvd. Deg.	Error Deg.	Allow. Error	% Error
34	1024	165	52	330	30	30	0	75	—	—	180	—	172	—	500	—	—	30S	—	—	3.0°	—
35	4120	205	32	240	5	45	25	105			210		19		4500			150S			0.5°	
36	2532	260	37	180	20	50	50	140			240		29		3000			120P			0.5°	
37	5680	233	24	330	30	55	75	170			270		15		6500			120S			0.5°	
38	1560	283	21	130	40	50	100	205			280		86		1000			30P			1.5°	
39	1727	293	45	200	10	40	125	235			290		43		2000			90P			0.5°	
40	4189	64	4	190	10	40	150	270			70		21		4000			60S			0.5°	
41	761	102	35	170	5	35	175	300			80		86		1000			90S			1.5°	
42	2592	119	53	330	20	45	200	335			90		43		2000			60P			0.5°	
43	5607	157	40	30	40	60	225	365			120		19		4500			90P			0.5°	
44	2538	152	27	120	0	25	250	400			150		34		2500			150P			0.5°	
											Sum				Sum				Sum			
											Ave. % Error				Ave. Error				Ave. % Error			
											Allow. % Error			100	Allow. Error		50		Allow. % Error			100
											Max. % Error				Max. Error				Max. % Error			
											Max. All. % Error			300	Max. All. Error		150		Max. All. % Error			300

MK. 3 MOD. 5 MK. 14 TORPEDO BASELINE=179 FEET OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Min.	C Target Course Deg.	S Target Speed Knots	Sz Stand. Speed Knots	Depth Set Feet	Uy Yards	Gyro Angle Observed Deg.	Observed Min.	Comp. Deg.	Error Min.	Allow. Error Min.	% Error	Torpedo Run Comp. Yards	Obsvd. Yards	Error Yards	Track Angle Comp. Deg.	Obsvd. Deg.	Error Deg.	Allow. Error	% Error
56	866	168	51	330	30	47.288	40	0	—	—	180	—	172	—	500	—	—	30S	—	—	3.0°	—
57	4133	205	26	240	5	47.288	20	25			210		19		4500			150S			0.5°	
58	2488	261	24	180	20	47.288	15	50			240		29		3000			120P			0.5°	
59	3605	224	30	330	30	47.288	15	75			270		21		4000			120S			0.5°	
60	1567	283	33	130	40	47.288	15	100			280		86		1000			30P			1.5°	
61	1692	292	12	200	10	47.288	30	125			290		43		2000			90P			0.5°	
62	4208	64	15	190	10	47.288	30	150			70		21		4000			60S			0.5°	
63	820	94	13	170	5	47.288	40	175			80		86		1000			90S			1.5°	
64	2573	115	37	330	20	47.288	20	200			90		43		2000			60P			0.5°	
65	7398	162	15	30	40	47.288	10	225			120		16		5500			90P			0.5°	
66	3043	151	23	120	0	47.288	50	250			150		29		3000			150P			0.5°	
											Sum				Sum				Sum			
											Ave. % Error				Ave. Error				Ave. % Error			
											Allow. % Error			100	Allow. Error		50		Allow. % Error			100
											Max. % Error				Max. Error				Max. % Error			
											Max. All. % Error			300	Max. All. Error		150		Max. All. % Error			300

Z_R=215 YDS. M_R=57.93 YDS.
Z_L=206 YDS. M_L=32.46 YDS.

Fwd Angle Solver Problems for use on SS-170 and SS-171

P=90 FT. Z=200 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	M Reach Yards	Gyro Angle Observed Deg.	Observed Min.	Comp. Deg.	Error Min.	Allow. Error Min.	% Error	Torpedo Run Comp. Yards	Obsvd. Yards	Error Yards	Track Angle Comp. Deg.	Obsvd. Deg.	Error Deg.	Allow. Error	% Error
1	1961	345	14	150	40	40	0	-50	—	—	0	—	86	—	1000	—	—	30S	—	—	1.5°	—
2	612	358	58	120	30	55	25	-25			30		172		500			90S			3.0°	
3	4106	41	1	90	20	50	50	0			60		15		6000			150S			0.5°	
4	2872	84	54	60	0	25	75	25			90		29		3000			150P			0.5°	
5	3880	112	47	10	10	35	100	50			100		21		4000			90P			0.5°	
6	4639	108	37	320	5	45	125	75			110		19		4500			30P			0.5°	
7	1191	230	4	10	40	50	150	100			250		86		1000			60S			1.5°	
8	1279	234	18	320	30	60	175	125			260		43		2000			120S			0.5°	
9	3551	256	7	30	20	45	200	150			270		29		3000			60S			0.5°	
10	3568	319	31	240	10	40	225	175			300		21		4000			120P			0.5°	
11	3868	340	10	210	5	30	250	200			330		25		3500			60P			0.5°	

Gyro Angle		Torpedo Run		Track Angle	
Sum		Sum		Sum	
Ave. % Error		Ave. Error		Ave. % Error	
Allow. % Error	100	Allow. Error	50	Allow. % Error	100
Max. % Error		Max. Error		Max. % Error	
Max. All. % Error	300	Max. All. Error	150	Max. All. % Error	300

P=90 FT. M=50 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	Z Radius of Turn Yards	Gyro Angle Observed Deg.	Observed Min.	Comp. Deg.	Error Min.	Allow. Error Min.	% Error	Torpedo Run Comp. Yards	Obsvd. Yards	Error Yards	Track Angle Comp. Deg.	Obsvd. Deg.	Error Deg.	Allow. Error	% Error
12	1961	345	14	150	40	40	0	75	—	—	0	—	86	—	1000	—	—	30S	—	—	1.5°	—
13	620	356	39	120	30	55	25	105			30		172		500			90S			3.0°	
14	4098	40	46	90	20	50	50	140			60		15		6000			150S			0.5°	
15	2864	84	59	60	0	25	75	170			90		29		3000			150P			0.5°	
16	3875	112	42	10	10	35	100	205			100		21		4000			90P			0.5°	
17	4639	108	21	320	5	45	125	235			110		19		4500			30P			0.5°	
18	1174	232	11	10	40	50	150	270			250		86		1000			60S			1.5°	
19	1271	236	18	320	30	60	175	300			260		43		2000			120S			0.5°	
20	3565	256	45	30	20	45	200	335			270		29		3000			60S			0.5°	
21	3590	318	57	240	10	40	225	365			300		21		4000			120P			0.5°	
22	3875	339	26	210	5	30	250	400			330		25		3500			60P			0.5°	

Gyro Angle		Torpedo Run		Track Angle	
Sum		Sum		Sum	
Ave. % Error		Ave. Error		Ave. % Error	
Allow. % Error	100	Allow. Error	50	Allow. % Error	100
Max. % Error		Max. Error		Max. % Error	
Max. All. % Error	300	Max. All. Error	150	Max. All. % Error	300

MK. 3 MOD. 10 MK. 14 TORPEDO BASELINE=90 FEET OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Min.	C Target Course Deg.	S Target Speed Knots	Sz Stand. Speed Knots	Depth Set Feet	Uy Yards	Gyro Angle Observed Deg.	Observed Min.	Comp. Deg.	Error Min.	Allow. Error Min.	% Error	Torpedo Run Comp. Yards	Obsvd. Yards	Error Yards	Track Angle Comp. Deg.	Obsvd. Deg.	Error Deg.	Allow. Error	% Error
45	1839	346	16	150	40	47.288	30	0	—	—	0	—	86	—	1000	—	—	30S	—	—	1.5°	—
46	654	351	39	120	30	47.288	15	25			30		172		500			90S			3.0°	
47	2009	35	38	90	20	47.288	15	50			60		29		3000			150S			0.5°	
48	1844	80	33	60	0	47.288	50	75			90		43		2000			150P			0.5°	
49	3807	108	43	10	10	47.288	40	100			100		21		4000			90P			0.5°	
50	4631	108	28	320	5	47.288	20	125			110		19		4500			30P			0.5°	
51	1331	227	36	10	40	47.288	15	150			250		86		1000			60S			1.5°	
52	4486	221	40	320	30	47.288	10	175			260		16		5500			120S			0.5°	
53	3651	255	28	30	20	47.288	20	200			270		29		3000			60S			0.5°	
54	3628	315	17	240	10	47.288	30	225			300		21		4000			120P			0.5°	
55	4810	336	11	210	5	47.288	40	250			330		19		4500			60P			0.5°	

Z_R=215 YDS. M_R=57.93 YDS.
Z_L=206 YDS. M_L=32.46 YDS.

Gyro Angle		Torpedo Run		Track Angle	
Sum		Sum		Sum	
Ave. % Error		Ave. Error		Ave. % Error	
Allow. % Error	100	Allow. Error	50	Allow. % Error	100
Max. % Error		Max. Error		Max. % Error	
Max. All. % Error	300	Max. All. Error	150	Max. All. % Error	300

Aft Angle Solver Problems for use on SS-170 and SS-171

P=150 FT. Z=200 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Target Bearing Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	M Reach Yards	Gyro Angle Observed Deg.	Gyro Angle Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
23	1014	165	44	330	30	30	0	−50	—	—	180	—	172	—	500	—	—	30S	—	—	3.0°	—
24	4117	205	57	240	5	45	25	−25			210		19		4500			150S			0.5°	
25	2548	261	0	180	20	50	50	0			240		29		3000			120P			0.5°	
26	5682	233	30	330	30	55	75	25			270		15		6500			120S			0.5°	
27	1546	283	58	130	40	50	100	50			280		86		1000			30P			1.5°	
28	1692	294	55	200	10	40	125	75			290		43		2000			90P			0.5°	
29	4200	63	19	190	10	40	150	100			70		21		4000			60S			0.5°	
30	732	99	3	170	5	35	175	125			80		86		1000			90S			1.5°	
31	2550	119	16	330	20	45	200	150			90		43		2000			60P			0.5°	
32	5588	158	3	30	40	60	225	175			120		19		4500			90P			0.5°	
33	2516	153	28	120	0	25	250	200			150		34		2500			150P			0.5°	
													Sum			Sum					Sum	
													Ave. % Error			Ave. Error					Ave. % Error	
													Allow. % Error	100		Allow. Error	50				Allow. % Error	100
													Max. % Error			Max. Error					Max. % Error	
													Max. All. % Error	300		Max. All. Error	150				Max. All. % Error	300

P=150 FT. M=50 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Target Bearing Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	Z Radius of Turn Yards	Gyro Angle Observed Deg.	Gyro Angle Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
34	1014	165	44	330	30	30	0	75	—	—	180	—	172	—	500	—	—	30S	—	—	3.0°	—
35	4112	205	36	240	5	45	25	105			210		19		4500			150S			0.5°	
36	2530	260	50	180	20	50	50	140			240		29		3000			120P			0.5°	
37	5674	233	29	330	30	55	75	170			270		15		6500			120S			0.5°	
38	1542	283	45	130	40	50	100	205			280		86		1000			30P			1.5°	
39	1690	294	8	200	10	40	125	235			290		43		2000			90P			0.5°	
40	4193	63	57	190	10	40	150	270			70		21		4000			60S			0.5°	
41	759	101	52	170	5	35	175	300			80		86		1000			90S			1.5°	
42	2588	119	42	330	20	45	200	335			90		43		2000			60P			0.5°	
43	5599	157	38	30	40	60	225	365			120		19		4500			90P			0.5°	
44	2529	152	21	120	0	25	250	400			150		34		2500			150P			0.5°	
													Sum			Sum					Sum	
													Ave. % Error			Ave. Error					Ave. % Error	
													Allow. % Error	100		Allow. Error	50				Allow. % Error	100
													Max. % Error			Max. Error					Max. % Error	
													Max. All. % Error	300		Max. All. Error	150				Max. All. % Error	300

MK. 3 MOD. 10 MK. 14 TORPEDO BASELINE=150 FEET OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Target Bearing Min.	C Target Course Deg.	S Target Speed Knots	Sz Stand. Speed Knots	Depth Set Feet	Uy Yards	Gyro Angle Observed Deg.	Gyro Angle Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
56	856	168	44	330	30	47.288	40	0	—	—	180	—	172	—	500	—	—	30S	—	—	3.0°	—
57	4124	205	29	240	5	47.288	20	25			210		19		4500			150S			0.5°	
58	2487	261	37	180	20	47.288	15	50			240		29		3000			120P			0.5°	
59	3563	225	10	330	30	47.288	15	75			270		21		4000			120S			0.5°	
60	1569	283	54	130	40	47.288	15	100			280		86		1000			30P			1.5°	
61	1696	292	30	200	10	47.288	30	125			290		43		2000			90P			0.5°	
62	4213	64	8	190	10	47.288	30	150			70		21		4000			60S			0.5°	
63	819	93	32	170	5	47.288	40	175			80		86		1000			90S			1.5°	
64	2569	115	25	330	20	47.288	20	200			90		43		2000			60P			0.5°	
65	7390	162	14	30	40	47.288	10	225			120		16		5500			90P			0.5°	
66	3035	151	18	120	0	47.288	50	250			150		29		3000			150P			0.5°	
													Sum			Sum					Sum	
													Ave. % Error			Ave. Error					Ave. % Error	
													Allow. % Error	100		Allow. Error	50				Allow. % Error	100
													Max. % Error			Max. Error					Max. % Error	
													Max. All. % Error	300		Max. All. Error	150				Max. All. % Error	300

Z_R=215 YDS. M_R=57.93 YDS.
Z_L=206 YDS. M_L=32.46 YDS.

Fwd Angle Solver Problems for use on SS-172, 173, 175, 177 to 194, 196, 197, 199 to 203

P=96 FT. Z=200 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Target Bearing Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	M Reach Yards	Gyro Angle Observed Deg.	Gyro Angle Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
1	1963	345	15	150	40	40	0	-50	—	—	0	—	86	—	1000	—	—	30S	—	—	1.5°	—
2	615	358	58	120	30	55	25	-25			30		172		500			90S			3.0°	
3	4109	40	59	90	20	50	50	0			60		15		6000			150S			0.5°	
4	2873	84	51	60	0	25	75	25			90		29		3000			150P			0.5°	
5	3879	112	44	10	10	35	100	50			100		21		4000			90P			0.5°	
6	4638	108	37	320	5	45	125	75			110		19		4500			30P			0.5°	
7	1967	227	35	10	40	50	150	100			250		57		1500			60S			1.0°	
8	1277	234	24	320	30	60	175	125			260		43		2000			120S			0.5°	
9	3550	256	10	30	20	45	200	150			270		29		3000			60S			0.5°	
10	3570	319	33	240	10	40	225	175			300		21		4000			120P			0.5°	
11	3870	340	11	210	5	30	250	200			330		25		3500			60P			0.5°	
													Sum			Sum					Sum	
													Ave. % Error			Ave. Error					Ave. % Error	
													Allow. % Error	100		Allow. Error	50				Allow. % Error	100
													Max. % Error			Max. Error					Max. % Error	
													Max. All. % Error	300		Max. All. Error	150				Max. All. % Error	300

P=96 FT. M=50 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Target Bearing Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	Z Radius of Turn Yards	Gyro Angle Observed Deg.	Gyro Angle Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
12	1963	345	15	150	40	40	0	75	—	—	0	—	86	—	1000	—	—	30S	—	—	1.5°	—
13	621	356	38	120	30	55	25	105			30		172		500			90S			3.0°	
14	4099	40	45	90	20	50	50	140			60		15		6000			150S			0.5°	
15	2864	84	56	60	0	25	75	170			90		29		3000			150P			0.5°	
16	3874	112	40	10	10	35	100	205			100		21		4000			90P			0.5°	
17	4638	108	17	320	5	45	125	235			110		19		4500			30P			0.5°	
18	1950	228	51	10	40	50	150	270			250		57		1500			60S			1.0°	
19	1270	236	24	320	30	60	175	300			260		43		2000			120S			0.5°	
20	3564	256	48	30	20	45	200	335			270		29		3000			60S			0.5°	
21	3592	318	59	240	10	40	225	365			300		21		4000			120P			0.5°	
22	3877	339	26	210	5	30	250	400			330		25		3500			60P			0.5°	
													Sum			Sum					Sum	
													Ave. % Error			Ave. Error					Ave. % Error	
													Allow. % Error	100		Allow. Error	50				Allow. % Error	100
													Max. % Error			Max. Error					Max. % Error	
													Max. All. % Error	300		Max. All. Error	150				Max. All. % Error	300

MK. 3 MOD. 11 & 12 MK. 14 TORPEDO BASELINE=96 FEET OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Target Bearing Min.	C Target Course Deg.	S Target Speed Knots	Sz Stand. Speed Knots	Depth Set Feet	Uy Yards	Gyro Angle Observed Deg.	Gyro Angle Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
45	1842	346	17	150	40	47.288	30	0	—	—	0	—	86	—	1000	—	—	30S	—	—	1.5°	—
46	657	351	42	120	30	47.288	15	25			30		172		500			90S			3.0°	
47	2011	35	36	90	20	47.288	15	50			60		29		3000			150S			0.5°	
48	1845	80	28	60	0	47.288	50	75			90		43		2000			150P			0.5°	
49	3806	108	40	10	10	47.288	40	100			100		21		4000			90P			0.5°	
50	4630	108	26	320	5	47.288	20	125			110		19		4500			30P			0.5°	
51	1329	227	41	10	40	47.288	15	150			250		86		1000			60S			1.5°	
52	4483	221	42	320	30	47.288	10	175			260		16		5500			120S			0.5°	
53	3650	255	30	30	20	47.288	20	200			270		29		3000			60S			0.5°	
54	3630	315	18	240	10	47.288	30	225			300		21		4000			120P			0.5°	
55	4812	336	12	210	5	47.288	40	250			330		19		4500			60P			0.5°	
													Sum			Sum					Sum	
													Ave. % Error			Ave. Error					Ave. % Error	
													Allow. % Error	100		Allow. Error	50				Allow. % Error	100
													Max. % Error			Max. Error					Max. % Error	
													Max. All. % Error	300		Max. All. Error	150				Max. All. % Error	300

Z_R=215 YDS. M_R=57.93 YDS.
Z_L=206 YDS. M_L=32.46 YDS.

Aft Angle Solver Problems for use on SS-172, 173, 175, 177 to 194, 196, 197, 199 to 203

P=170 FT. Z=200 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	M Reach Yards	GYRO ANGLE Observed Deg.	Observed Min.	Comp. Deg.	Error Min.	Allow. Error Min.	% Error	TORPEDO RUN Comp. Yards	Obsvd. Yards	Error Yards	TRACK ANGLE Comp. Deg.	Obsvd. Deg.	Error Deg.	Allow. Error	% Error
23	1021	165	49	330	30	30	0	-50	—	—	180	—	172	—	500	—	—	30S	—	—	3.0°	—
24	4123	205	54	240	5	45	25	-25			210		19		4500			150S			0.5°	
25	2549	260	51	180	20	50	50	0			240		29		3000			120P			0.5°	
26	5687	233	26	330	30	55	75	25			270		15		6500			120S			0.5°	
27	1545	283	43	130	40	50	100	50			280		86		1000			30P			1.5°	
28	1690	294	43	200	10	40	125	75			290		43		2000			90P			0.5°	
29	4197	63	24	190	10	40	150	100			70		21		4000			60S			0.5°	
30	734	99	34	170	5	35	175	125			80		86		1000			90S			1.5°	
31	2554	119	36	330	20	45	200	150			90		43		2000			60P			0.5°	
32	5596	158	5	30	40	60	225	175			120		19		4500			90P			0.5°	
33	2487	153	35	120	0	25	250	200			150		34		2500			150P			0.5°	
													Sum			Sum					Sum	
													Ave. % Error			Ave. Error					Ave. % Error	
													Allow. % Error	100		Allow. Error	50				Allow. % Error	100
													Max. % Error			Max. Error					Max. % Error	
													Max. All. % Error	300		Max. All. Error	150				Max. All. % Error	300

P=170 FT. M=50 YARDS OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Min.	C Target Course Deg.	S Target Speed Knots	S'z Torpedo Speed Knots	Uy Yards	? Radius of Turn Yards	GYRO ANGLE Observed Deg.	Observed Min.	Comp. Deg.	Error Min.	Allow. Error Min.	% Error	TORPEDO RUN Comp. Yards	Obsvd. Yards	Error Yards	TRACK ANGLE Comp. Deg.	Obsvd. Deg.	Error Deg.	Allow. Error	% Error
34	1021	165	49	330	30	30	0	75	—	—	180	—	172	—	500	—	—	30S	—	—	3.0°	—
35	4117	205	34	240	5	45	25	105			210		19		4500			150S			0.5°	
36	2531	260	41	180	20	50	50	140			240		29		3000			120P			0.5°	
37	5677	233	26	330	30	55	75	170			270		15		6500			120S			0.5°	
38	1540	283	31	130	40	50	100	205			280		86		1000			30P			1.5°	
39	1687	293	56	200	10	40	125	235			290		43		2000			90P			0.5°	
40	4190	64	2	190	10	40	150	270			70		21		4000			60S			0.5°	
41	760	102	21	170	5	35	175	300			80		86		1000			90S			1.5°	
42	2591	119	50	330	20	45	200	335			90		43		2000			60P			0.5°	
43	5606	157	40	30	40	60	225	365			120		19		4500			90P			0.5°	
44	2535	152	25	120	0	25	250	400			150		34		2500			150P			0.5°	
													Sum			Sum					Sum	
													Ave. % Error			Ave. Error					Ave. % Error	
													Allow. % Error	100		Allow. Error	50				Allow. % Error	100
													Max. % Error			Max. Error					Max. % Error	
													Max. All. % Error	300		Max. All. Error	150				Max. All. % Error	300

MK. 3 MOD. 11 & 12 MK. 14 TORPEDO BASELINE=170 FEET OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Min.	C Target Course Deg.	S Target Speed Knots	Sz Stand. Speed Knots	Depth Set Feet	Uy Yards	GYRO ANGLE Observed Deg.	Observed Min.	Comp. Deg.	Error Min.	Allow. Error Min.	% Error	TORPEDO RUN Comp. Yards	Obsvd. Yards	Error Yards	TRACK ANGLE Comp. Deg.	Obsvd. Deg.	Error Deg.	Allow. Error	% Error
56	863	168	49	330	30	47.288	40	0	—	—	180	—	172	—	500	—	—	30S	—	—	3.0°	—
57	4130	205	27	240	5	47.288	20	25			210		19		4500			150S			0.5°	
58	2488	261	28	180	20	47.288	15	50			240		29		3000			120P			0.5°	
59	3603	224	32	330	30	47.288	15	75			270		21		4000			120S			0.5°	
60	1568	283	40	130	40	47.288	15	100			280		86		1000			30P			1.5°	
61	1694	292	18	200	10	47.288	30	125			290		43		2000			90P			0.5°	
62	4210	64	13	190	10	47.288	30	150			70		21		4000			60S			0.5°	
63	820	94	00	170	5	47.288	40	175			80		86		1000			90S			1.5°	
64	2572	115	34	330	20	47.288	20	200			90		43		2000			60P			0.5°	
65	7396	162	15	30	40	47.288	10	225			120		16		5500			90P			0.5°	
66	3041	151	22	120	0	47.288	50	250			150		29		3000			150P			0.5°	
													Sum			Sum					Sum	
													Ave. % Error			Ave. Error					Ave. % Error	
													Allow. % Error	100		Allow. Error	50				Allow. % Error	100
													Max. % Error			Max. Error					Max. % Error	
													Max. All. % Error	300		Max. All. Error	150				Max. All. % Error	300

Z_R=215 YDS. M_R=57.93 YDS.
Z_L=206 YDS. M_L=32.46 YDS.

Fwd Angle Solver Problem for use on SS-167 and SS-168

MK. 3 MOD. 8 MK. 15 TORPEDO — BASELINE=145.5 FEET — OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Target Bearing Min.	C Target Course Deg.	S Target Speed Knots	Sz Stand. Speed Knots	Depth Set Feet	Uy Yards	Gyro Angle Observed Deg.	Gyro Angle Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
45	525	24	56	240	40	46.937	15	0	—	—	0	—	286	—	300	—	—	60P	—	—	4.5°	—
46	1968	336	4	90	40	46.937	20	25			30		43		2000			120S			1.0°	
47	4198	52	14	255	20	46.937	30	50			45		29		3000			30P			1.0°	
48	4454	32	37	150	20	46.937	40	75			60		21		4000			90S			0.5°	
49	6569	62	48	195	10	46.937	10	100			75		15		5900			60S			0.5°	
50	1475	90	45	300	30	46.937	50	125			90		86		1000			30P			1.5°	
51	2493	275	10	300	5	46.937	15	150			270		29		3000			150S			1.0°	
52	5003	309	10	210	5	46.937	20	175			300		17		5000			90P			0.5°	
53	1999	319	44	105	0	46.937	30	200			315		43		2000			30S			1.0°	
54	1018	23	00	270	30	46.937	40	225			330		86		1000			120P			1.5°	
55	4128	353	16	315	10	46.937	10	250			345		17		5000			150P			0.5°	
											Sum				Sum				Sum			
	Z_R=286 YDS.				M_R=34.8 YDS.						Ave. % Error				Ave. Error				Ave. % Error			
	Z_L=272 YDS.				M_L=71.8 YDS.						Allow. % Error			100	Allow. Error		50		Allow. % Error			100
											Max. % Error				Max. Error				Max. % Error			
											Max. All. % Error			300	Max. All. Error		150		Max. All. % Error			300

Aft Angle Solver Problem for use on SS-167 and SS-168

MK. 3 MOD. 8 MK. 15 TORPEDO — BASELINE=181 FEET — OWN COURSE=0°

Pb. No.	R Range Yards	Br Target Bearing Deg.	Br Target Bearing Min.	C Target Course Deg.	S Target Speed Knots	Sz Stand. Speed Knots	Depth Set Feet	Uy Yards	Gyro Angle Observed Deg.	Gyro Angle Observed Min.	Gyro Angle Comp. Deg.	Gyro Angle Error Min.	Gyro Angle Allow. Error Min.	Gyro Angle % Error	Torpedo Run Comp. Yards	Torpedo Run Obsvd. Yards	Torpedo Run Error Yards	Track Angle Comp. Deg.	Track Angle Obsvd. Deg.	Track Angle Error Deg.	Track Angle Allow. Error	Track Angle % Error
56	396	187	57	60	10	46.937	10	0	—	—	180	—	285	—	300	—	—	60P	—	—	4.5°	—
57	6069	228	35	105	30	46.937	40	25			195		17		5000			90P			1.0°	
58	2750	220	23	150	10	46.937	30	50			210		29		3000			120P			1.0°	
59	2016	220	42	75	0	46.937	15	75			225		43		2000			30P			0.5°	
60	7597	279	31	150	40	46.937	10	100			240		15		5900			90P			0.5°	
61	2570	257	40	300	5	46.937	20	125			270		28		3000			150S			1.5°	
62	532	31	28	150	40	46.937	20	150			90		86		1000			120S			1.0°	
63	5147	103	21	225	5	46.937	15	175			105		17		5000			60S			0.5°	
64	4256	97	57	210	20	46.937	30	200			120		21		4000			90S			1.0°	
65	2886	128	29	285	20	46.937	40	225			135		43		2000			30S			1.5°	
66	607	211	37	120	30	46.937	50	250			150		86		1000			150P			0.5°	
											Sum				Sum				Sum			
	Z_R=286 YDS.				M_R=34.8 YDS.						Ave. % Error				Ave. Error				Ave. % Error			
	Z_L=272 YDS.				M_L=71.8 YDS.						Allow. % Error			100	Allow. Error		50		Allow. % Error			100
											Max. % Error				Max. Error				Max. % Error			
											Max. All. % Error			300	Max. All. Error		150		Max. All % Error			300

ANGLE SOLVER NOTES

1. Sz, Torpedo Running Speed, the uniform running speed in knots at proof depth after the initial acceleration period is complete.

2. S'z, Corrected Torpedo Running Speed, is Torpedo Running Speed corrected for set depth.

3. Uy, the Torpedo Run for a given time minus the distance the Torpedo would have travelled during the same time at Corrected Torpedo Running Speed, in yards.

SOUND BEARING CONVERTER TESTS

1. SR/1000 is used to set in the values of Target travel during the time of sound travel, where S=Target Speed in knots, R=Range in yards. In the solution of the problem Target travel is to be added to one half Target Length and is accomplished by setting the value of Target Length against an index line representing the value of SR/1000 for the particular problem.

2. Set in values of Target Bearing, Range, Target Speed, Target Length against SR/1000, and Target Course as given in the following problems.

3. For each of the above settings record values of Sound Bearing. (See also Fig. 246, page 225, Notes 5 and 6.)

OWN SPEED So=0 KNOTS								OWN COURSE Co=0°						
								SOUND BEARING Fr.						
Pb. No.	Br Target Bearing Deg.	R Range Yards	S Target Speed Knots	2P Target Length Feet	SR/1000 Target Lth. Ind. Feet	C Target Course Deg.	P Sound Baseline Yards	Computed Deg	Computed Min.	Observed Deg.	Observed Min.	Error (Min.)	Allow Error (Min.)	Percent Error
1	0	300	30	300	9	60	+16	351	17	—	—	—	57	—
2	30	300	30	300	9	90	+16	22	48				57	
3	210	1000	5	450	5	150	+16	213	20				17	
4	210	1000	10	450	10	90	+16	213	26				17	
5	60	2500	20	600	50	285	+16	62	13				6	
6	270	2500	40	1000	100	60	+16	267	19				6	
7	270	5000	40	1000	200	60	+16	268	28				4	
8	60	5000	20	600	100	285	+16	61	15				4	
9	315	8000	5	750	40	225	+16	315	55				4	
10	315	8000	10	750	80	135	+16	314	55				4	
													Sum	
													Average % Error	
													Allow % Error	
													Max. % Error	
													Max. Allow. % Error	

OWN SPEED So=0 KNOTS								OWN COURSE Co=0°						
								SOUND BEARING Fr.						
Pb. No.	Br Target Bearing Deg.	R Range Yards	S Target Speed Knots	2P Target Length Feet	SR/1000 Target Lth. Ind. Feet	C Target Course Deg.	P Sound Baseline Yards	Computed Deg.	Computed Min.	Observed Deg.	Observed Min.	Error (Min.)	Allow Error (Min.)	Percent Error
1	0	300	30	300	9	60	30	351	17	—	—	—	57	—
2	30	300	30	300	9	90	30	24	6				57	
3	210	1000	5	450	5	150	30	212	57				17	
4	210	1000	10	450	10	90	30	213	2				17	
5	60	2500	20	600	50	285	30	62	30				6	
6	270	2500	40	1000	100	60	30	267	0				6	
7	270	5000	40	1000	200	60	30	268	18				4	
8	60	5000	20	600	100	285	30	61	23				4	
9	315	8000	5	750	40	225	30	315	51				4	
10	315	8000	10	750	80	135	30	314	51				4	
													Sum	
													Average % Error	
													Allow % Error	100
													Max. % Error	
													Max. Allow. % Error	300

NOTE: These problems are for ships having a Sound Base Line indicated. To test the Sound Bearing Converter aboard a ship having a different Sound Base Line, use the problems furnished for the particular ship.

This page is blank.

INSTALLATION

To install a Torpedo Data Computer, it is necessary to follow the procedure outlined in the following section.

SECTION 7

1. Place the Position Keeper and Angle Solver into the ship's compartment where they are mounted. Remove the upper and lower front covers of the Position Keeper and the front cover of the Angle Solver.

2. Place a small parallel clamp on the Target Angle shaft and another on the Relative Target Bearing shaft of the aft Differential Unit in the Angle Solver so that upon removal of the shipping clamps of those two shafts, their zero settings will not be lost. Remove the shipping clamps.

3. Feed the cables which are now inside of the Angle Solver, so that they project out of the hole in the left side of the case.

4. If necessary, turn the Range coupling in the left side of the Angle Solver case as far as it will go in the counterclockwise direction. This indicates that the Range Stops in the two Resolver Units have reached their "8000 yard" ends.

5. Turn the Range Input Crank of the Position Keeper until the Range Counters read 8000 yards.

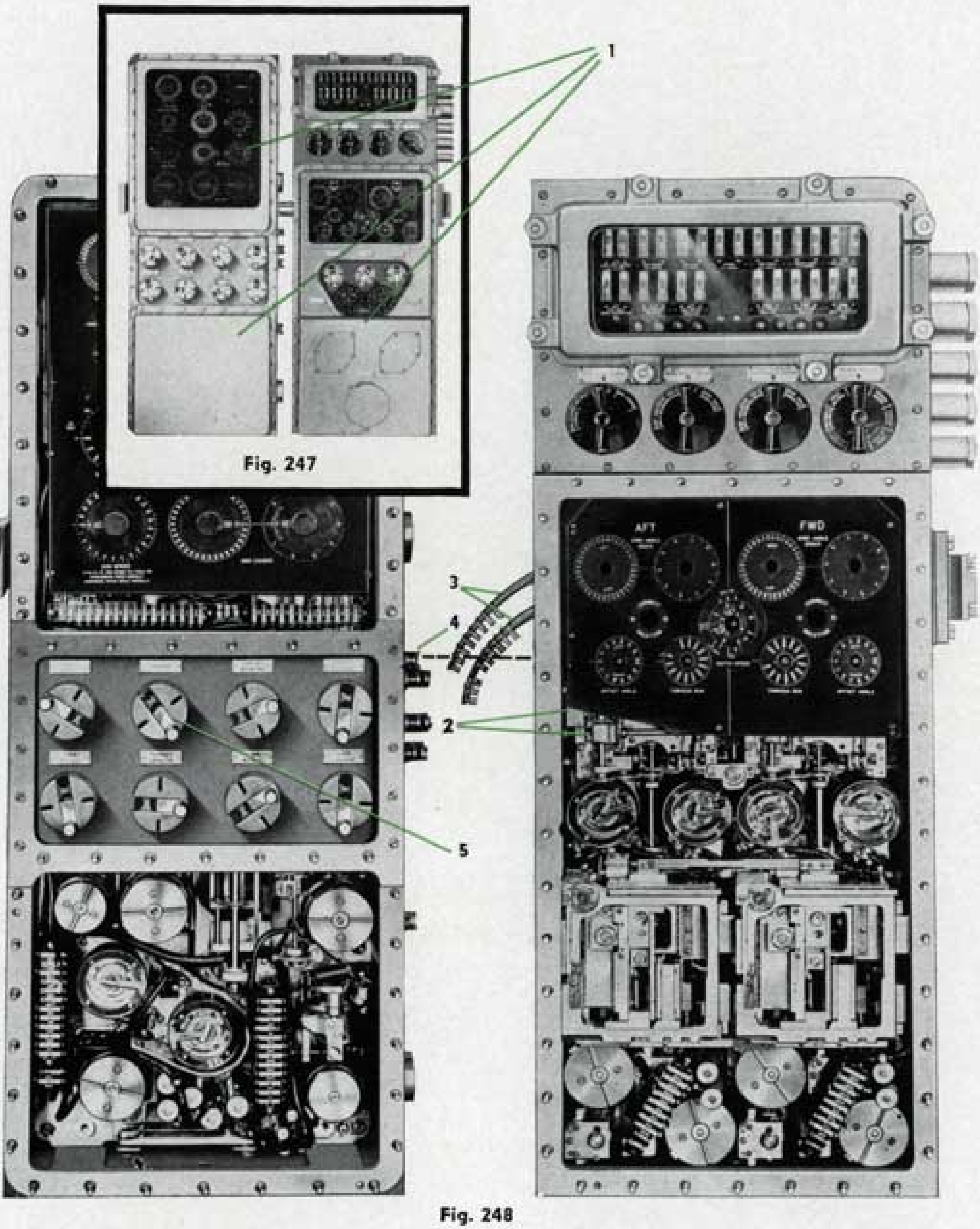


Fig. 247

Fig. 248

6. If necessary, turn the Target Speed coupling in the left side of the Angle Solver case as far as it will go in the clockwise direction. This indicates that the Target Speed Stops in the Proportionator Units have reached their "zero knot" ends.

7. Turn the Target Speed Input Crank of the Position Keeper until the Target Speed Dial reads zero knots.

8. Turn the Target Bearing Crank of the Position Keeper until Relative Target Bearing reads zero degrees.

9. Turn the Own Course Input Crank until Own Course is on zero and the Target Course Input Crank until Target Course is on 180 degrees.

10. Inspect the two G—Br Stops in the Angle Solver to see if they are in their zero positions. The low and high speedmarks on the Stops should be used as a means of checking for zero position. If either is off zero it should be set back by turning the G—Br Follow-up Motor adjacent to it.

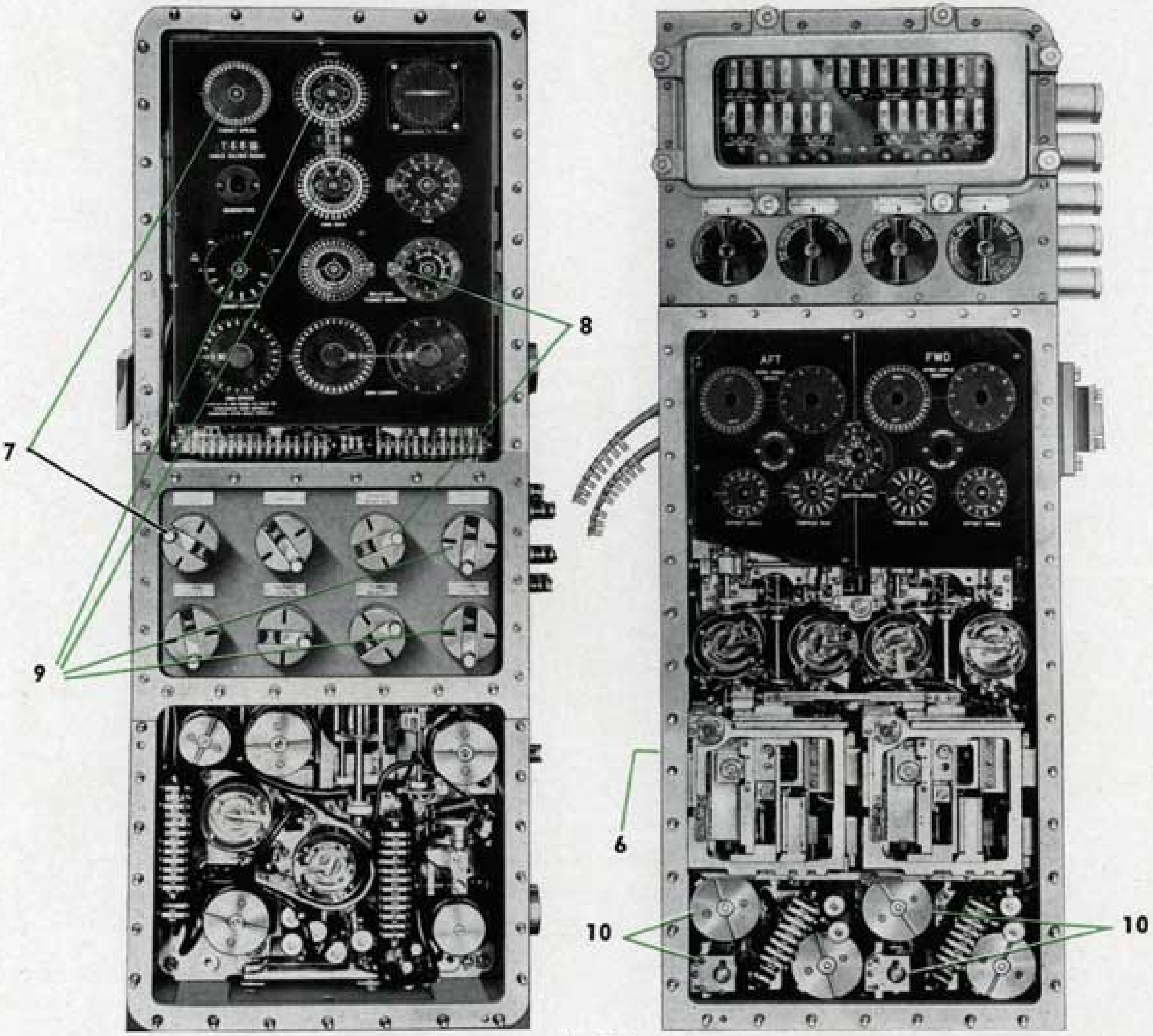


Fig. 249

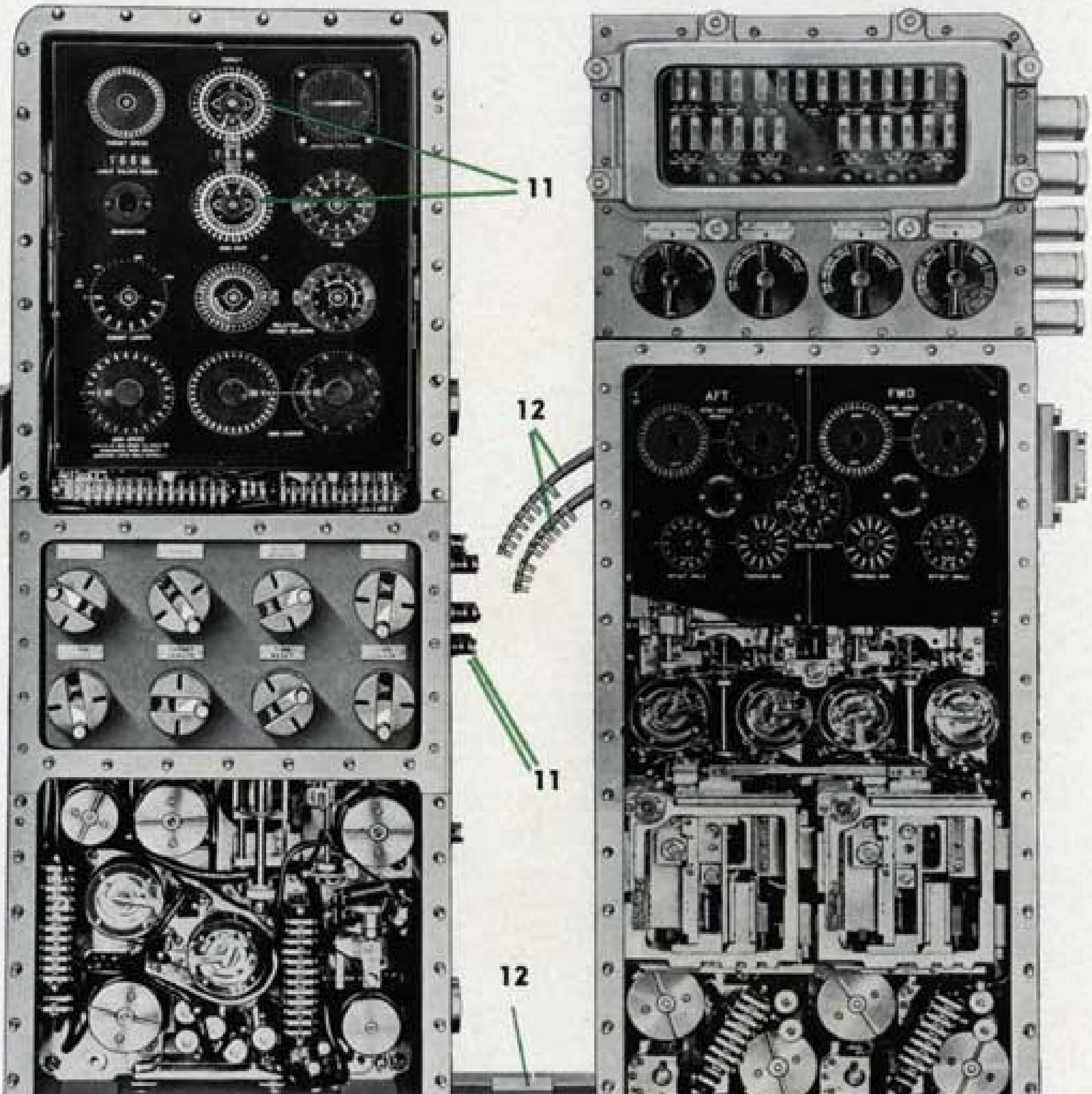


Fig. 250

11. Turn the G—Br couplings in the right side of the Position Keeper until the Gyro Angle arrows and Track Angle arrows of the Target Dial extend toward the arrows of the Own Ship Dial.

12. All of the interconnecting couplings of the Position Keeper and Angle Solver are now properly set and the two cases should now be placed together, carefully feeding the cables of the Angle Solver into the hole in the right side of the Position Keeper. The best method of performing this operation is to place the two cases on the long mounting plate which is supplied with the instrument. Then by using the keys, which are secured to the plate, as a guide, slide the cases toward each other.

13. Fasten the two cases together with the three bolts which are set into place in the Position Keeper and screwed into the left side of the Angle Solver case. A special offset screwdriver is supplied in the spare parts box. In order to accomplish this task it is necessary to remove the dial plate so that the upper bolt may be inserted. The dial plate should be replaced after the bolts have been installed.

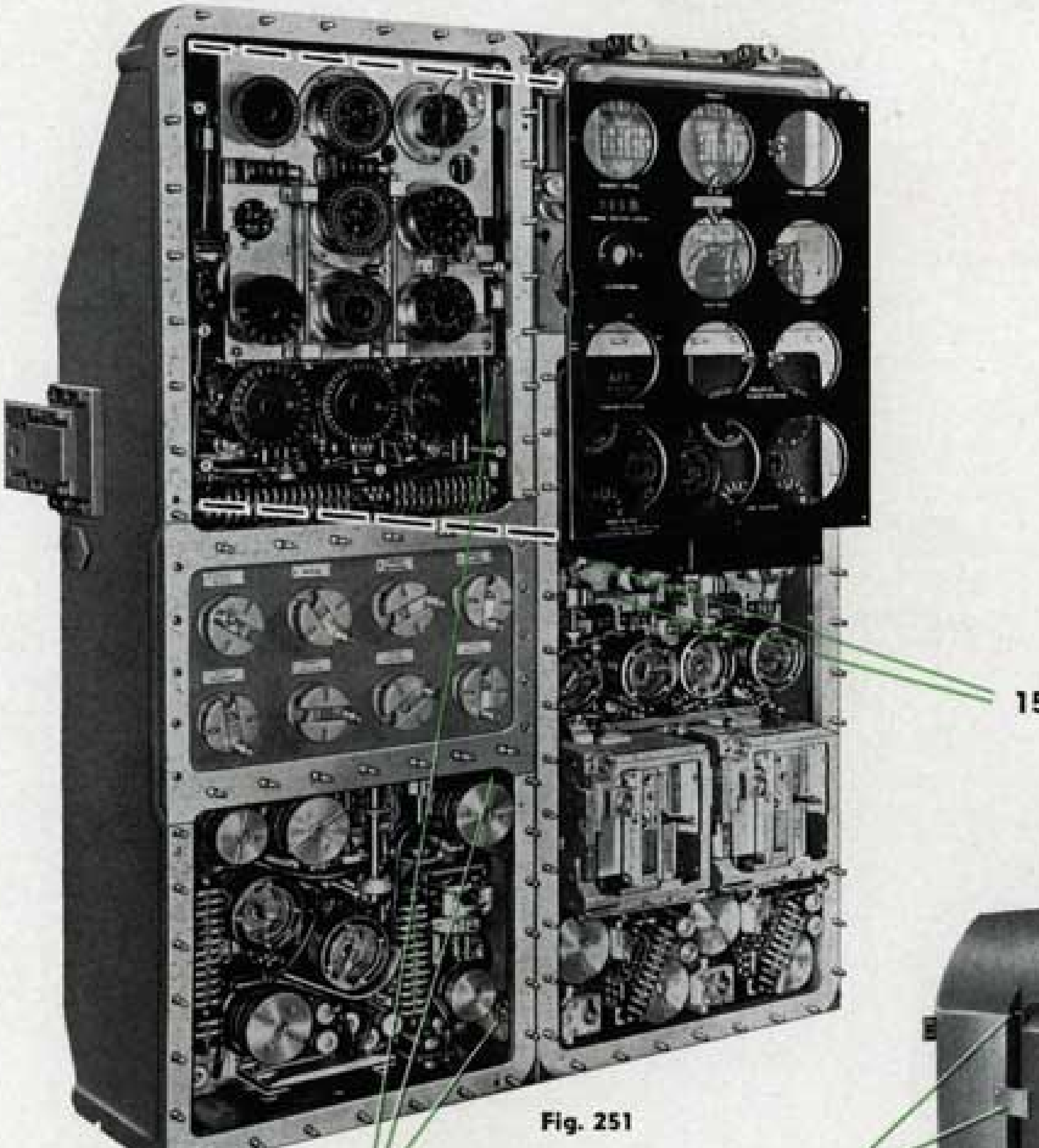


Fig. 251

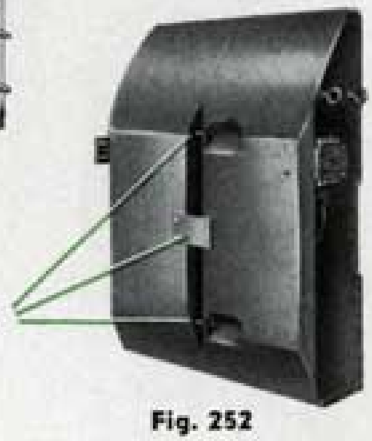


Fig. 252

14. Bolt the short plate to the back of the two cases. Screw in the two bolts which hold the two cases together in the back.

15. Remove the clamps from the Target Angle and Br Relative Target Bearing shafts.

16. Set the Base Line in both the fwd and aft Cam Units to agree with ship on which the Computer is installed.

Slide the M carriage to the right. Next turn the Target Bearing Handcrank in the Position Keeper until the engraved index mark can be seen adjacent to the circular engraved band in the Cam Unit. When the engraved mark is in view, hold the Gyro Angle input securely and slip the band (using a screwdriver in the notches of the band) until the graduation for the desired Base Line is aligned with the engraved mark. The band is graduated in yards.

CAUTION: In adjusting the band, never go below 0 or above 100, or damage to the Resolver may result.

17. Set $Z_R - Z_L$ and $M_R - M_L$ to agree with the torpedoes being used. As previously mentioned the cams in the Cam Unit are split so that this difference in turning radius of the torpedo may be set into the cams. To make this adjustment, the two hexagonal shaped access covers must be removed from the cover of the Angle Solver. The Z Cams are the two on the lower shaft of the Cam Unit. $Z_R - Z_L$ is set in by turning, with a screwdriver, a screw located on the cam shaft between the two cams. It may be necessary to turn the Target Bearing Handcrank in the Position Keeper in order to bring the screw head into an accessible position. The linear scale which indicates the setting of the cams is graduated in units of 10 yards, the circular scale is graduated in units of 1 yard. The adjusting screw should be turned clockwise to increase* the value of $Z_R - Z_L$.

The values of Reach may also differ for right and left turns of the torpedoes being used. The M Cams are the two on the upper shaft of the Cam Unit. The adjustment for $M_R - M_L$ is made in the same manner as is done for $Z_R - Z_L$. The adjusting screw is turned clockwise to increase the value of $M_R - M_L$.

The values of Z_R, Z_L, M_R, and M_L can be obtained from the tactical data supplied with each torpedo. $Z_R - Z_L$ and $M_R - M_L$ can then be calculated from these values.

*NOTE: If the tactical data indicates that $Z_R - Z_L$ or $M_R - M_L$ is a negative quantity the value is set in, in an INCREASING direction; if a positive quantity, in a DECREASING direction. See Page 88 in chapter on Function.

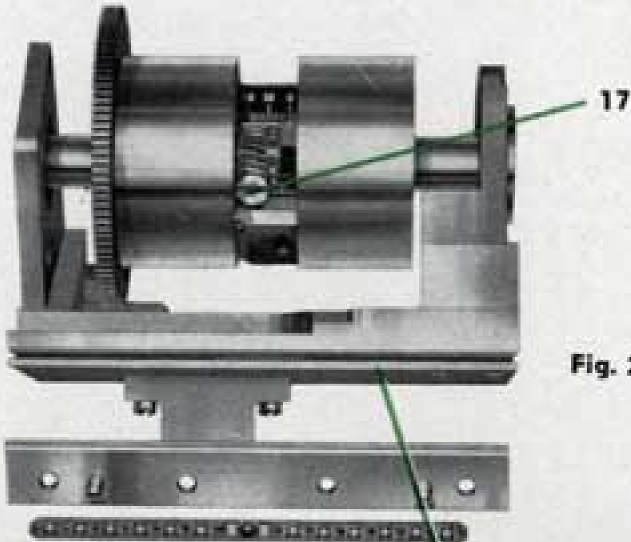


Fig. 253

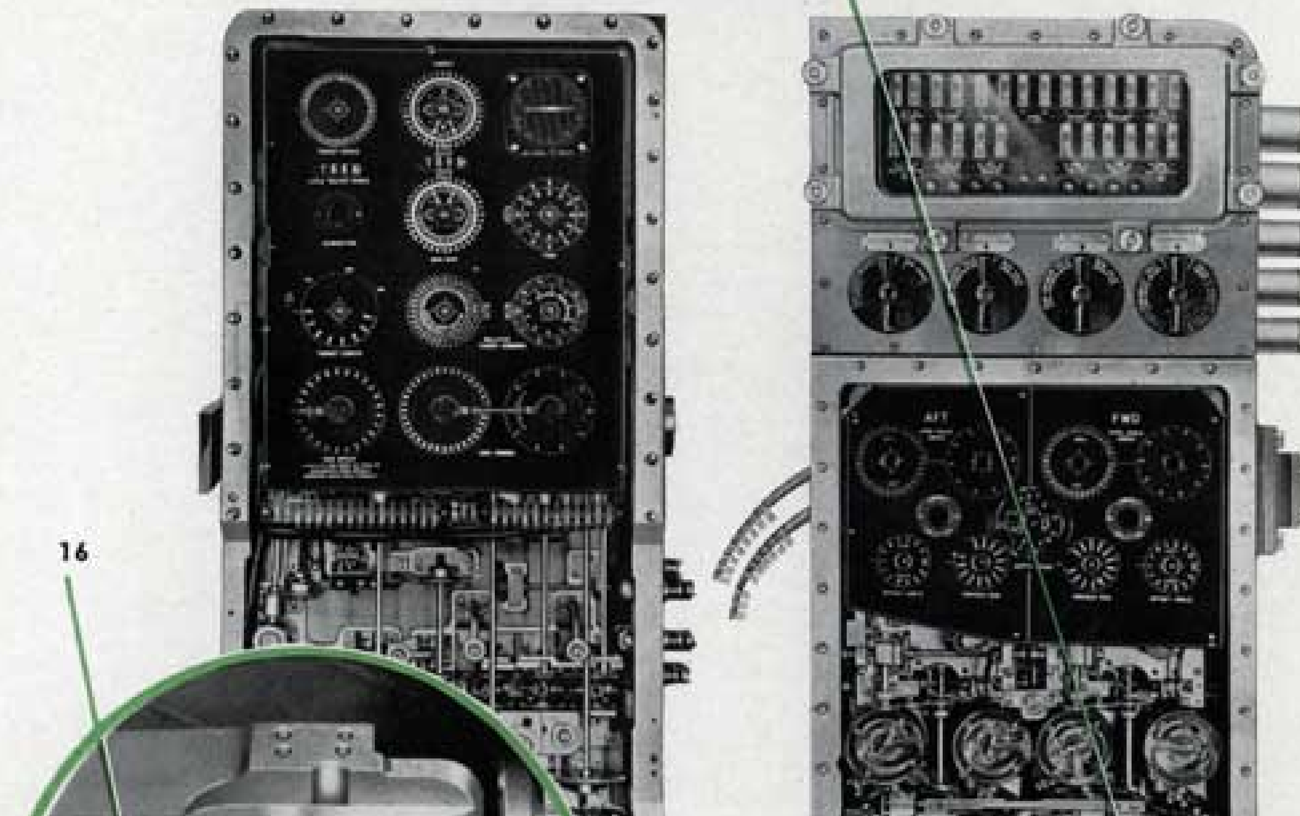


Fig. 254

Fig. 255

18. Connect the wires, which were fed into the Position Keeper from, the Angle Solver, to their respective terminal blocks.

19. Replace the three front covers of the instrument. Use the following procedure for replacing the Angle Solver cover.

When replacing this cover it is necessary to set three inputs on the front of the chassis. 1. Turn the Torpedo Run Difference, Uy, input gear clockwise as far as it will go. 2. Move the Turning Radius, Z, carriages and Reach, M, carriages to the right as far as they will go. 3. Now set the Uy, Z and M Dials on the front of the cover to read as follows:

Set Uy at 0

When Z_R is greater than Z_L, set Z at $75+(Z_R-Z_L)$.

When Z_L is equal to, or greater than Z_R, set Z at 75.

When M_R is greater than M_L, set M at $-50+(M_R-M_L)$.

When M_L is equal to, or greater than M_R, set M at -50.

The values of Z_R, Z_L, M_R, and M_L are supplied with the torpedo.

The cover may now be installed, being careful not to move any of the values set above, when meshing their respective gears.

20. Fasten the rubber insulated mounting pads to each side of the instrument.

21. Raise the complete instrument high enough to enable the long mounting plate and the three rubber insulated mounting pads to be screwed to the base of the instrument. The two outer pads and the plate are secured at the same time as the bolts pass through both pieces. When mounting the plate, place the wider portion, relative to the clearance holes, toward the front of the instrument.

22. If the 18 holes in the angle mount on the bulkhead are already drilled, the plate and mounting pads should be completely secured. Then the instrument should be set into place and secured, both at its bottom mounting pads by means of six bolts each, and at the mounting pads at each side by means of one bolt each.

23. If the 18 holes are not drilled, secure the bottom mounting pads by only four bolts each. Then set the instrument temporarily in place so that the final position of the three bottom mounting pads is located. Mark the location of each pad with a scriber or in some similar manner.

The bolts which screw up from below and into the bottom mounting pads screw into three long tapped bars rather than into nuts, this method being easier than with loose nuts because of the confined space within the pads.

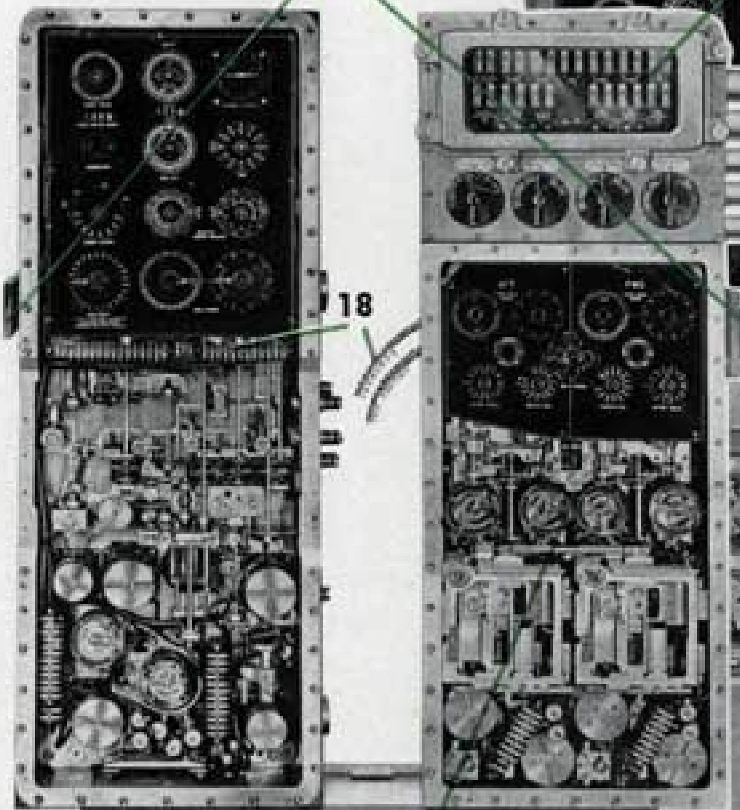


Fig. 256

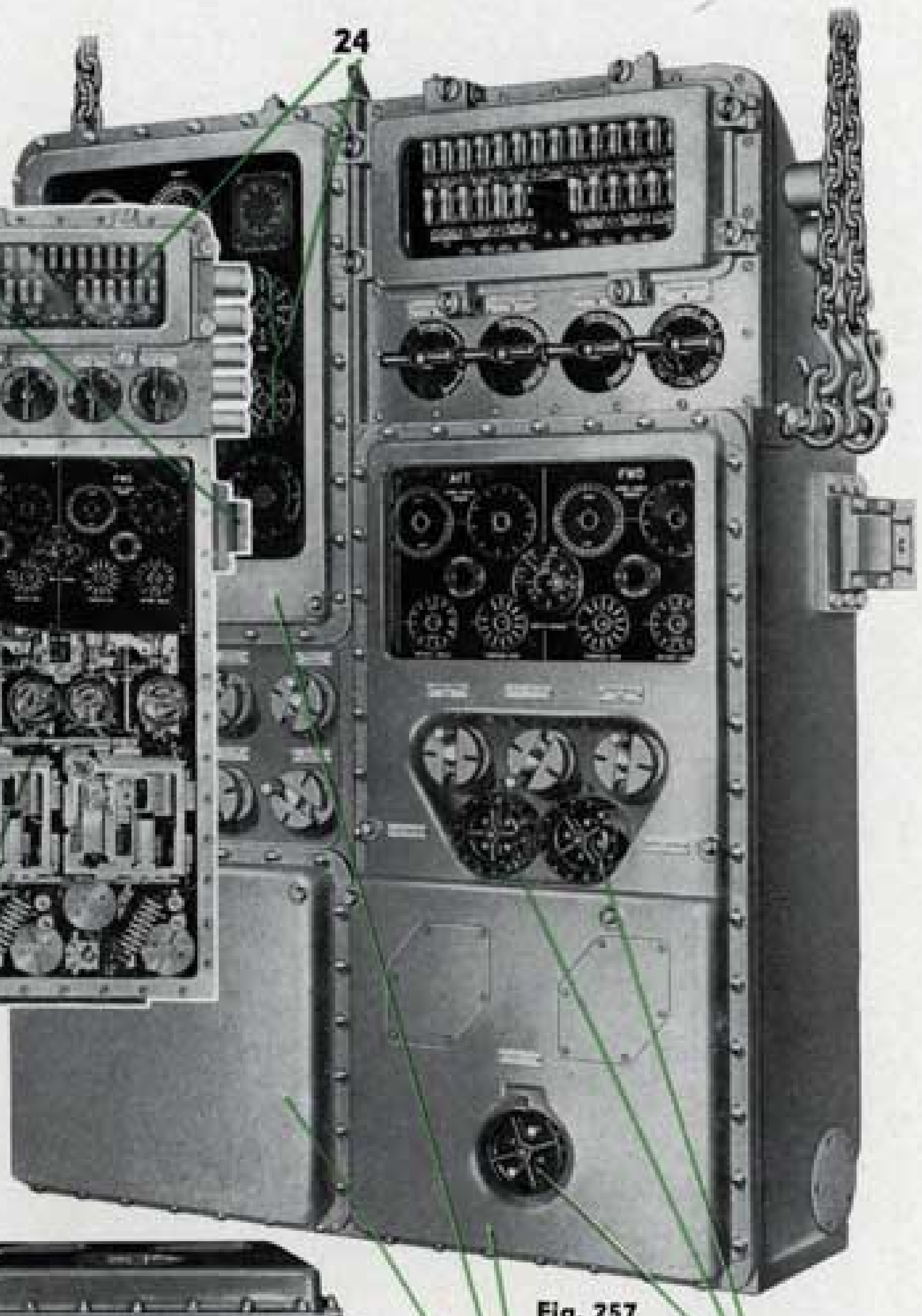


Fig. 257

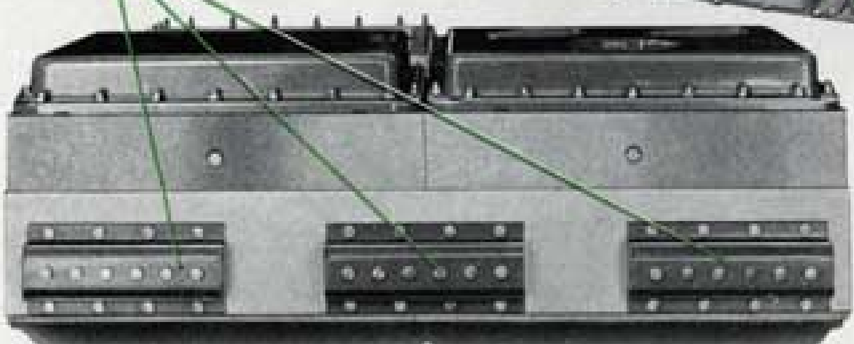


Fig. 258

Remove the instrument from the bulkhead. Remove the bottom pads from the instrument. Set each pad in its marked position and, using the six holes in each pad as guides, drill the 18 required holes (clearance for 5/16″) in the angle mount on the bulkhead. Proceed as in step 22.

24. The necessary wiring should now be run through the terminal tubes and connected to the respective terminal blocks in the electrical compartment at the top of the Angle Solver.

ADJUSTMENTS

Whenever adjustments are made to the instrument, only competent personnel should make them. Before making any changes a thorough check should be made to ascertain just what adjustments are necessary to correct any trouble, thus decreasing chances of disarranging the entire system.

SECTION 8

THERMOSTAT

In order for the instrument to operate at the normal temperature of 74 degrees, the thermostat should be set to that temperature.

TIME MOTOR GOVERNOR

The Governor is set at the factory to be accurate within ± ¼ of 1% anywhere in the range from 103 to 127 volts. If adjustments are necessary they should be made at both extremes of voltage. Checking may be accomplished by comparing the Time Dial readings with those of a stop watch.

In order to speed up the Governor, screw the two adjustable weights toward the center.

When the weights are screwed out from the center the Governor is slowed down. When making adjustments it is imperative that the weights be turned an equal amount and that they are securely tightened with the locking nuts after adjustment.

SLIP CLUTCHES

The slip clutches of the eight Follow-up Motors, the Time Motor, the $\triangle$R Follow-up Head gearing and the $\triangle$R Follow-up Motor gearing (not the one on the motor shaft itself) are not readily adjustable, since they are pinned at the factory for the proper setting.

Changing the setting requires replacement of the friction discs or changing the spring.

The required setting in each case is as follows:

The Follow-up Motors—The clutch should be set so that if the motor is running at 127 volts, and the output gear is stopped, the motor will keep turning for several revolutions and then stall.

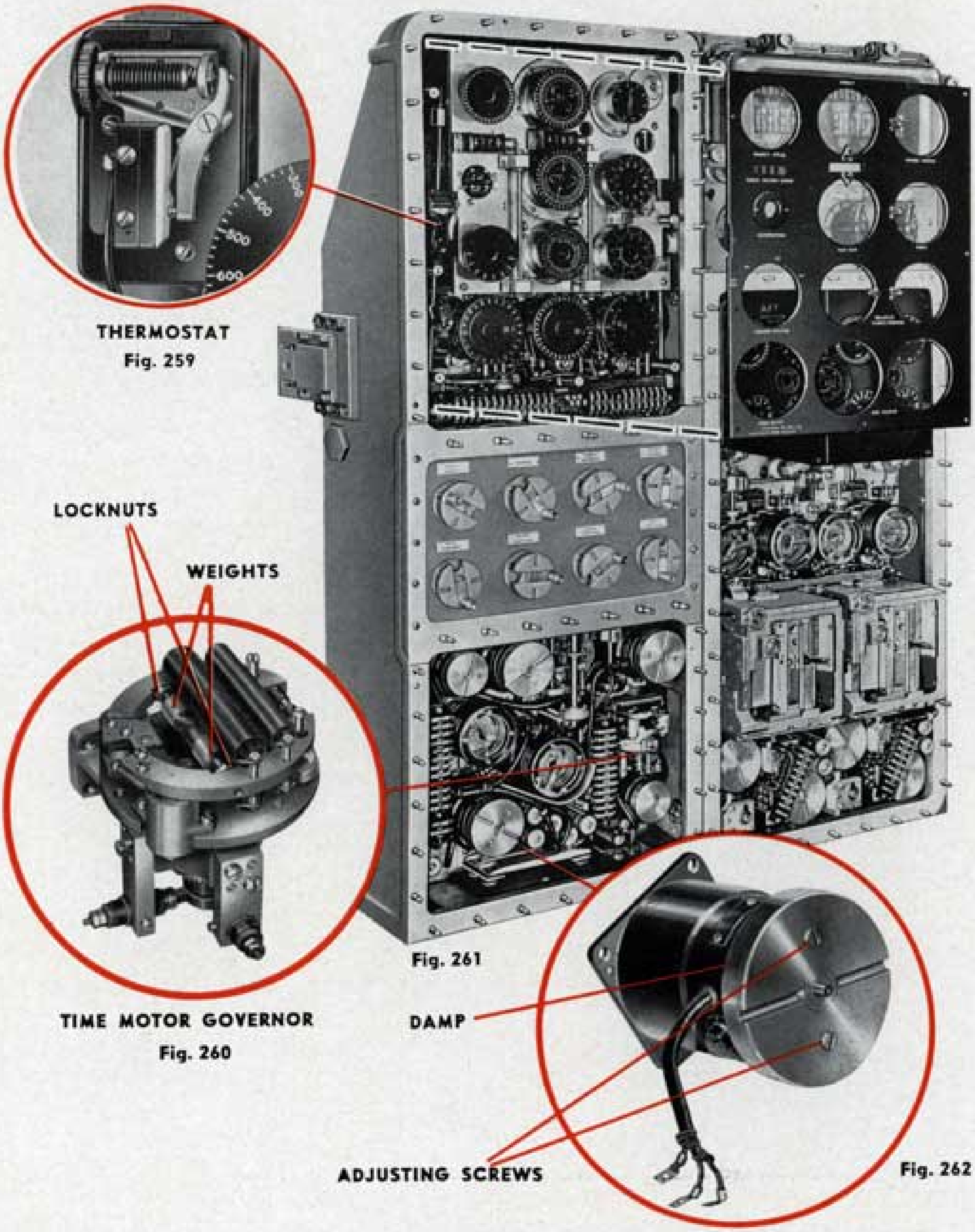
Time Motor—The clutch should be set to slip at from 35-36 ounce-inches.

$\triangle$R Follow-up Head gearing—The clutch should be set to slip at from 25-48 ounce-inches.

$\triangle$R Follow-up Motor gearing—The clutch should be set to slip at from 8-9 pound-inches.

FOLLOW-UP MOTOR DAMPS

The follow-up motor damps must be adjusted individually to suit each case, the



THERMOSTAT
Fig. 259

TIME MOTOR GOVERNOR
Fig. 260

Fig. 261

Fig. 262

main object being to achieve the smoothest following possible. Screwing the two screws inward increases the friction, while screwing them outward decreases the friction.

ANGLE SOLVER RANGE STOP SWITCHES (Located in the Position Keeper)

The Range Stop operates to limit the range to between 300 and 8000 yards. The switches should de-energize the fields of the motor at approximately 308 and 7992 yards. That is, when the nut is travelling in a direction of decreasing range, the upper switch should open the circuit when the range reaches 308 yards. Conversely, when the nut is moving downward, indicating increasing range, the lower switch should open the circuit when the value of range reaches 7992 yards. See Fig. 263.

OFFSET ANGLE ZERO DETENT SWITCHES

These switches are normally closed but should open when the Offset Angle Stop is in the zero or mid-position. This allows the solenoid to be de-energized causing the plunger to fall into the detent in the driving gear of the Stop. The switches should also close to energize the solenoid before the driving gear has made one revolution in either direction from zero. See Fig. 266.

INTEGRATOR UNIT AND DIVIDER UNIT DISCS

These seven discs should each have a spring tension of from 10 to 16 pounds, which may be tested by pulling the disc away from the roller while slightly oscillating the disc. At the moment the roller ceases to turn, the spring pressure on the spring scale, by means of which the disc is being pulled, should be read. See Fig. 264.

As in the case of the slip clutches, these springs can not be adjusted as their setting is permanently pinned at the factory. Therefore, any necessary change must be accomplished by replacing the spring.

SYNCHRO MOTOR AND GENERATOR ELECTRICAL ZERO

The low and high speed aft and fwd Gyro Angle Order Synchro Generators can be adjusted by following steps 231 to 247 on Page 212.

The three synchro motors with their follow-up heads which are located in the Position Keeper can be set by following steps 67 through 71 on Page 182. The trolley may be loosened from the synchro rotor by means of a synchro wrench as shown in Fig. 201, Page 175. The spacing between the rolls may be adjusted by loosening the screws holding them to the trolley. See Fig. 268.

MECHANICAL FOLLOW-UP HEADS

Care should be taken to avoid strain on either the inner member (trolley) or the outer member, since damage might result to the rails or gearing to which the members are geared. Hold the inner unit by hand whenever the nut is loosened or tightened. Otherwise, the wrench will tend to turn the inner member. See Fig. 265.

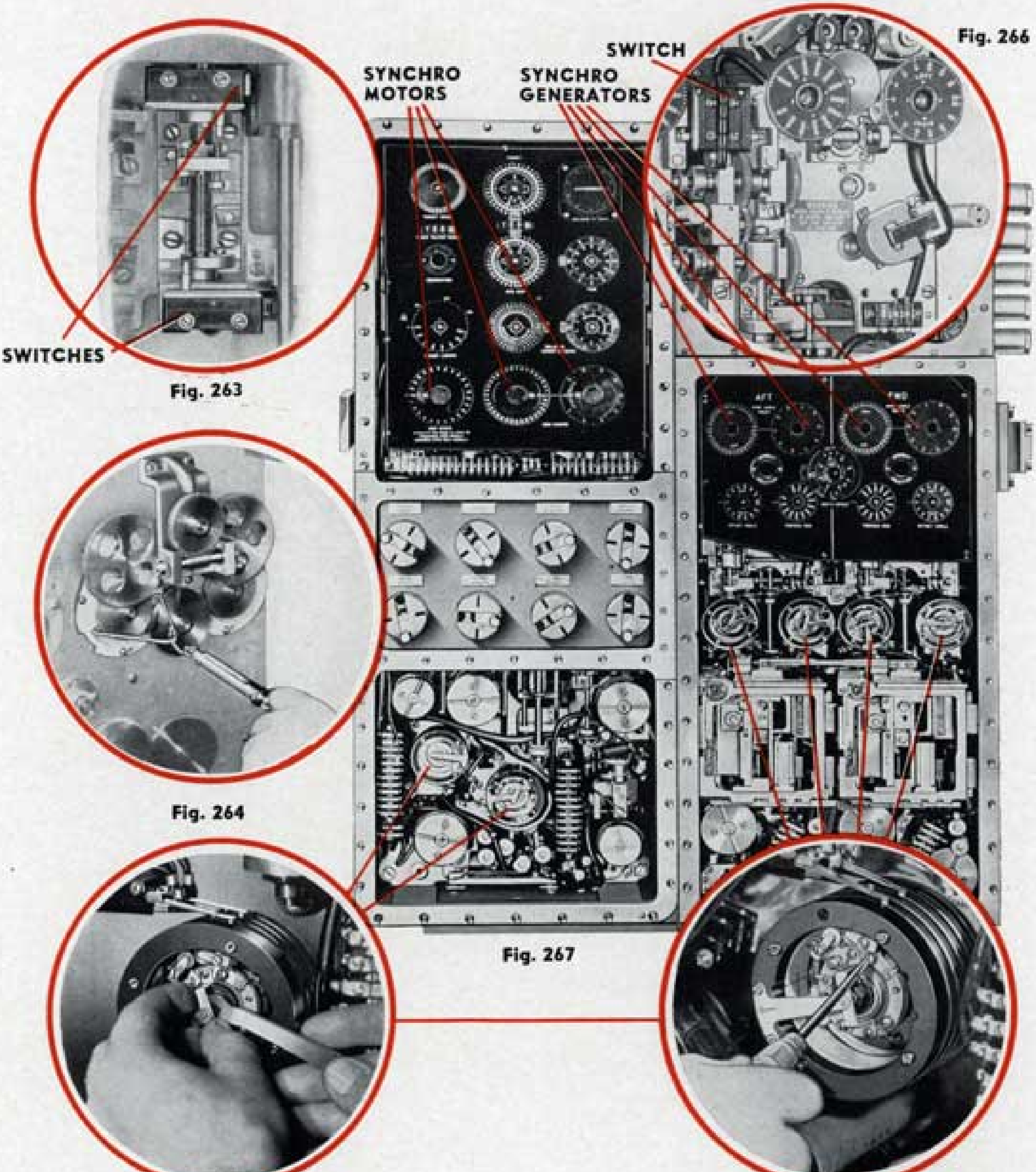


Fig. 263

Fig. 264

Fig. 265

Fig. 266

Fig. 267

Fig. 268

The adjustment of the two rollers of the high speed portion of the inner member should be such that the least possible amount of dead space exists without causing "hunting" of the follow-up motor. To make the adjustment for dead space, loosen the two screws of the roller to be adjusted. Then turn the small eccentric adjusting screw in the proper direction, finally tightening the two screws, Fig. 268.

CORRECT SOLUTION LIGHT SWITCHES

The Correct Solution Light Switches behind the Gyro Angle Order Dials, and those located adjacent to the Torpedo Run Dials should be adjusted in the following manner:

1. Set Relative Target Bearing on zero degrees.
2. Turn the fwd and aft G—Br Follow-up Motors and Stops until all of the Gyro Angle Order Dials read zero degrees.
3. Remove the dial plate and the fwd and aft 1-speed Gyro Angle Order Dials to provide access to the cams behind the dials.
4. Adjust the aft cam so that the cam disc lobes are superimposed, the assembly now having a lobe no wider than that of one of the discs.
5. Position the center lobe (leaving the dials on zero) on the contact roller. This sets the cam approximately for a spread of $\pm$ 150°. The positioning is done by loosening three screws which clamp the cam discs to the gear hub. If a different Gyro Angle spread is desired, in order to match the particular type of Torpedo being used, the lobes of the cam should be fanned out equal distances from the roller.
6. The cam has now been set so that clockwise turning of the Relative Target Bearing Handcrank will lift the roller and operate the switch plunger when the Relative Target Bearing Dial reaches a value of 180° plus the maximum desired value of right Gyro Angle (increasing from lower value), and further so that counterclockwise turning of the handcrank will actuate the roller and switch when the dial reaches a value of 180° minus the minimum left Gyro Angle desired (decreasing from higher value). The setting should be as accurate as possible for the particular type of Torpedo being used. The overall width of the lobe should be adjusted to meet this condition.
7. Leaving G—Br on zero degrees, turn Relative Target Bearing to read 180 degrees. The Gyro Angle Order Dials are now on 180 degrees.
8. Set the fwd cam in a manner similar to that used for the aft cam, setting the cam disc lobes together.
9. If a total spread of Gyro Angle of $\pm$ 150° is not desired, the lobes of the cams should be fanned out as in Step 5.
10. Check the fwd cam by turning the Relative Target Bearing Handcrank in a clockwise direction. When the dial reaches the maximum value in an increasing direction for the particular Torpedo being used (increasing from lower values) the switch should operate. When the handcrank is turned in a counterclockwise direction the switch should operate when the dial reaches the maximum value in the decreasing direction (decreasing from higher values). Again, this adjustment should be made as accurately as possible.
11. Replace the dials and the dial plate. The switches behind the Torpedo Run Dials should be set in the following manner. Set each one by this procedure, adjusting first one then the other.

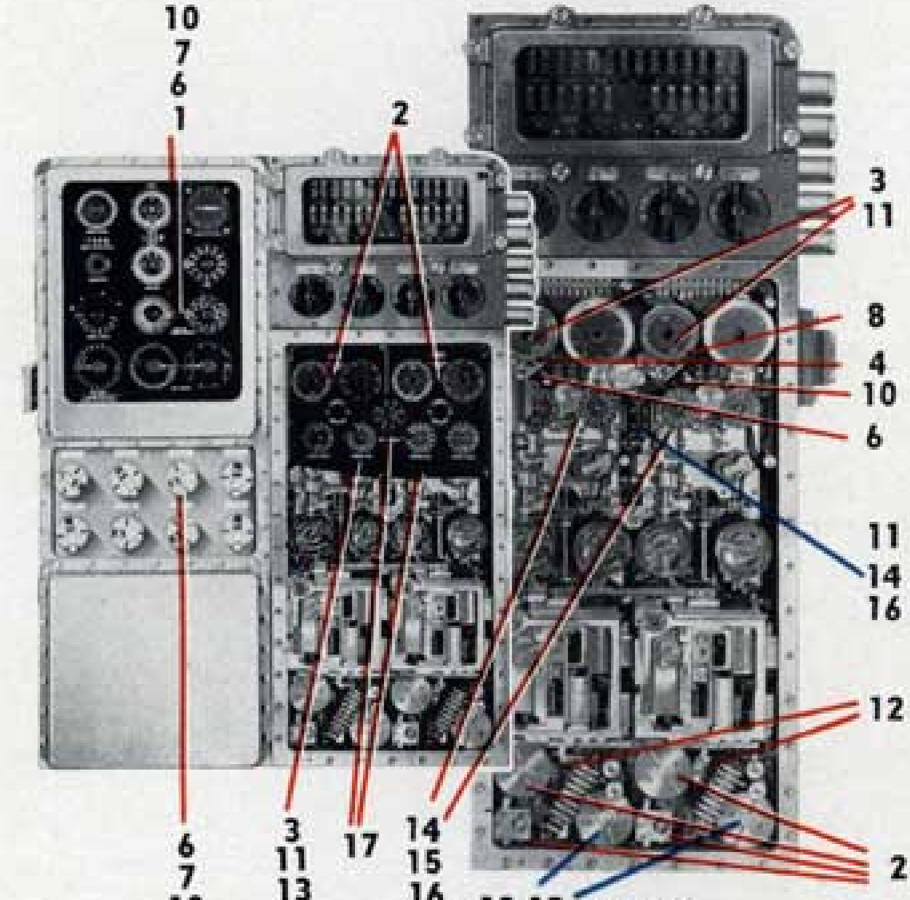


Fig. 269

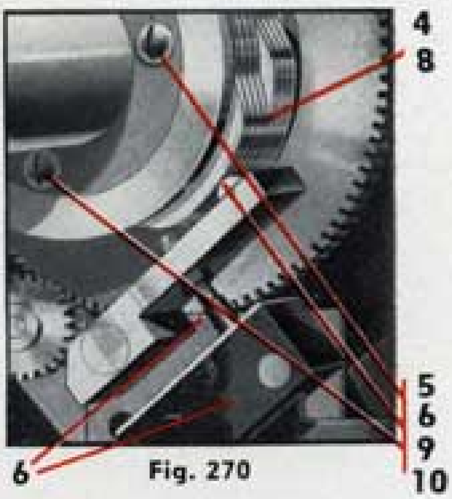


Fig. 270

12. Turn the $\tan^{-1}$ T'a Follow-up Motor and Stop until the Torpedo Run Dial reads 300 yards.

13. Remove the dial plate. (The plate must be removed and replaced several times while reading the dial and setting the cam.)

14. The cam will be seen to be similar to the cams previously set, and also is secured by three clamping screws. Fan out the discs of this cam so that the 300 yard end of the cam just actuates the switch (pushing it in until it clicks) when at 300 yards, or a few yards before reaching 300, when the dial is turned in a decreasing (counterclockwise) direction. Never allow it to actuate after going below 300 yards. The adjustment can be made at the adjusting screw on the roller arm as well as at the cam itself. After the adjustment is made, replace the dial.

15. Turn the $\tan^{-1}$ T'a Follow-up Motor until the dial reads the value of maximum torpedo run for the particular torpedo being used. In order to get a high reading S'z must be first set in at a high value.

16. Adjust the high end of the cam (leaving the 300 yard end untouched) until it is set to actuate the switch at the maximum torpedo run desired, or a few yards before this value is reached, when the dial is turned in an increasing (clockwise) direction. Never allow it to actuate after exceeding the maximum desired value.

17. Secure the dial plates and install the transparent Depth Set Dial. This dial should be replaced so that the engraved line, which is about ¼ inch counterclockwise from the 50 foot mark of the 15LO marking, is directly over the 25 knot engraving of the S'z Dial. On instruments that do not have the 15LO marking, the index mark may be recognized as a straight line with a small circle in the middle.

DIALS

The setting of each dial is described in detail in the section on "Disassembly and Reassembly", and the respective procedure should be followed for the particular dial to be adjusted.

SOUND BASE LINE (Distance from the Sound Bearing Receiver to Periscope)

Access to the Sound Base Line Resolver is had by removing the large hex head plug in the left side of the Position Keeper case. Turn the Target Bearing Handcrank until it is possible to insert a screwdriver in the head of the locking screw behind the dial. Loosen the locking screw. Then readjust Target Bearing until the screwdriver can be inserted in the slot in the center of the dial. Set the dial at the desired value of Sound Base Line (fwd or aft), retighten the locking screw and replace the plug in the case.

TUBE BASE LINE (Distance from Torpedo Tube Muzzle to midway between the Periscopes)

In order to change the Tube Base Line setting on the Cam Unit, it is necessary to remove the front cover of the Angle Solver. Then slide the M carriage to the right.

Next turn the Target Bearing Handcrank in the Position Keeper until the engraved index mark can be seen adjacent to the circular engraved band in the Cam Unit.

When the engraved index mark is in view, hold the Gyro Angle input securely and slip the band (using a screwdriver in the notches of the band) until the graduation for the desired Base Line is aligned with the engraved mark. The band is graduated in yards. See Fig. 143C, Page 140.

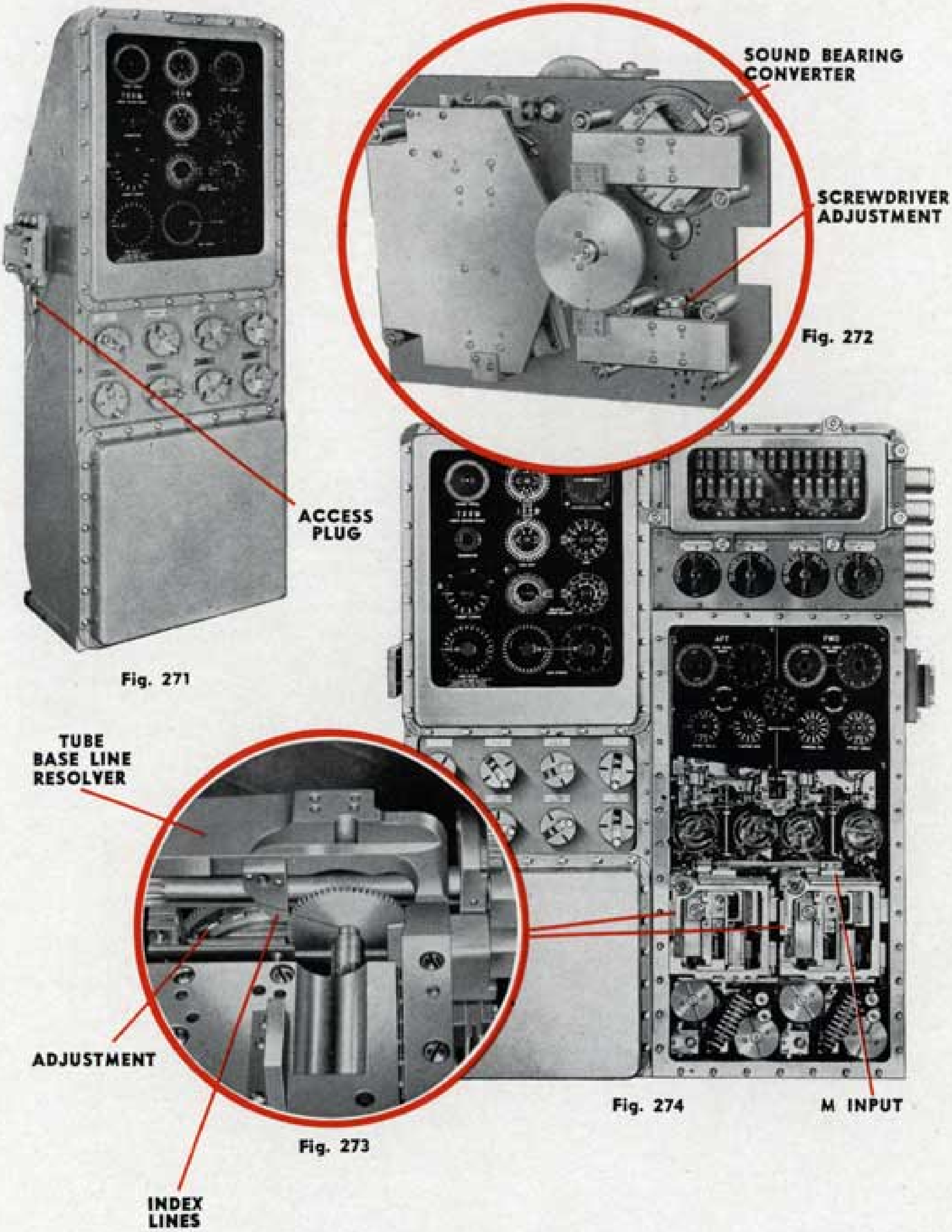


Fig. 271

Fig. 272

Fig. 273

Fig. 274

CAUTION: In adjusting the band, never go below 0 or above 100, or damage to the Resolver may result.

$Z_R - Z_L$ and $M_R - M_L$ SETTINGS

Some torpedoes have different turning radii to the right and to the left. As previously mentioned the cams in the Cam Unit are split so that this difference in turning radius may be set into the cams. To make this adjustment, the two hexagonal-shaped access covers must be removed from the cover of the Angle Solver. The Z Cams are the two on the lower shaft of the Cam Unit. $Z_R - Z_L$ is set in by turning, with a screwdriver, a screw located on the cam shaft between the two cams. Refer to Fig. 275. It may be necessary to turn the Target Bearing Handcrank in the Position Keeper in order to bring the screw head into an accessible position. The straight scale which indicates the setting of the cams is graduated in units of 10 yards. The cylindrical scale is graduated every yard. The adjusting screw should be turned clockwise to increase the value of $Z_R - Z_L$.

The values of Reach, M, may also differ for right and left turns of the torpedoes. The M Cams are the two on the upper shaft of the Cam Unit. The adjustment for $M_R - M_L$ is made in the same manner as is done for $Z_R - Z_L$, as described above.

The values of Z_R, Z_L, M_R, and M_L can be obtained from the tactical data supplied with each torpedo. $Z_R - Z_L$ and $M_R - M_L$ can then be calculated from these values.*

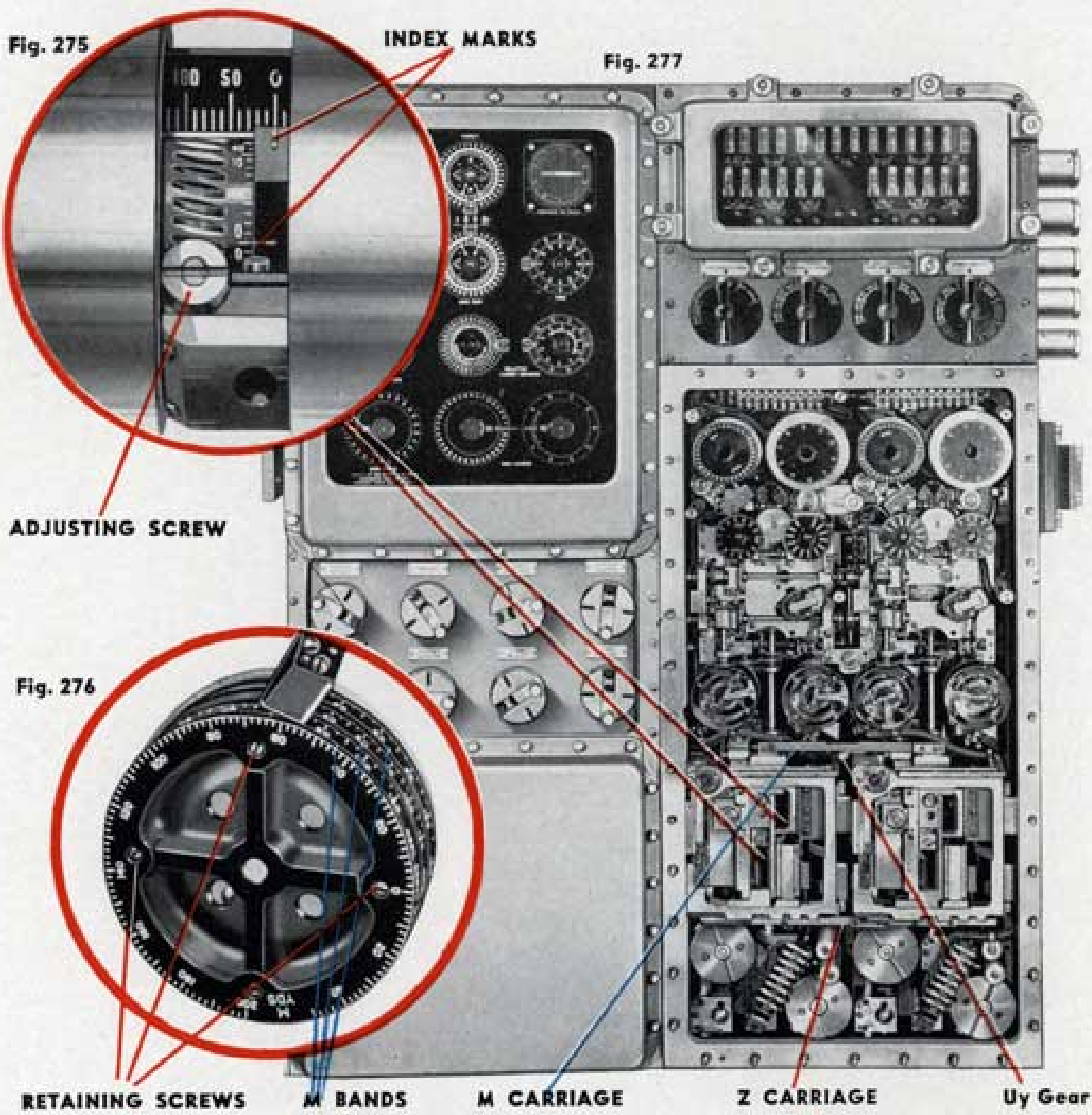
REPLACING Uy and M BANDS ON INPUT DIALS

In order to replace the bands on either of these dials, it is necessary to remove the four screws which hold the assembly of bands and retainers together. Refer to Fig. 276. Next remove the retainers and bands alternately from the assembly base. Select the bands desired to be installed, and replace them between the retainers, making sure that the engraved line on each band is aligned with the engraved line on the base. Secure the assembly by replacing the four screws.

REPLACING THE ANGLE SOLVER FRONT COVER

When replacing this cover it is necessary to set three input shafts on the front of the chassis. 1. Turn the Uy input gear clockwise as far as it will go. 2. Move the Z carriages and M carriages to the right as far as they will go. 3. Now set the Uy, Z, and M Dials on the front of the cover to read as follows:

*Note: If the tactical data indicates that $Z_R - Z_L$ or $M_R - M_L$ is a negative quantity the value is set in, in an INCREASING direction; if a positive quantity, in a DECREASING direction.



Set U at 0.

When Z_R is greater than Z_L, set Z at $+75 + (Z_R - Z_L)$.

When Z_L is equal to, or greater than Z_R, set Z at $+75$.

When M_R is greater than M_L, set M at $-50 + (M_R - M_L)$.

When M_L is equal to, or greater than M_R, set M at -50.

The values of Z_R, Z_L, M_R, and M_L are supplied with the torpedo.

The cover may now be installed, being careful not to move any of the values set above, when meshing their respective gears.

This page is blank.

LUBRICATION

The following section describes the lubrication of the various elements. It is essential that the instrument be kept free of foreign matter. Covers should be removed only when absolutely necessary and replaced as soon as possible.

SECTION 9

Proper lubrication depends upon the amount of operation to which the instrument is subjected. Excessive oiling is of no value and only serves to collect foreign matter on various parts of the instrument on which it drops.

Upon removing an element for adjustment or repair, the opportunity should be taken to lubricate all parts that are thereby made accessible. Before replacing the element, properly lubricate it also.

A log should be kept showing the elements lubricated and the dates of their lubrication.

SYNCHRO BEARINGS

While it is desirable to lubricate synchro bearings every 24 months, it is not a requirement. However, if a synchro is removed for any reason, the opportunity should be taken to lubricate its bearings with Shell Aircraft Hydraulic Gear Oil V-226, if they have not been lubricated in the previous 18 months. Use sufficient oil to form a thin film on the races.

Fig. 278

FOLLOW-UP HEADS

It is not necessary to clean the contact rollers, segments, slip rings, or brushes of the follow-up heads, with one exception. Never use emery cloth, sand paper, or crocus cloth on these parts. The contact rollers and segments are made of a material whose oxide does not prevent electrical conduction. Cleaning does no good and causes needless wear. However, if the contact surfaces should become coated with a film of oil or grease they should be wiped with a clean cloth saturated with alcohol. Any lint left by the cloth should be removed with a clean brush. The exception is the slip rings of the five follow-up heads in the position keeper. These should be lubricated lightly with Gulf Precision Grease No. 1. A grade B grease (Navy Spec. 14L3b) may be used *only* if the Gulf Precision Grease No. 1 is not obtainable.


Fig. 279

ROUTINE CARE OF INTEGRATOR DISCS AND TIME MOTOR

After every 100 hours operation of the instrument the following routine is necessary.

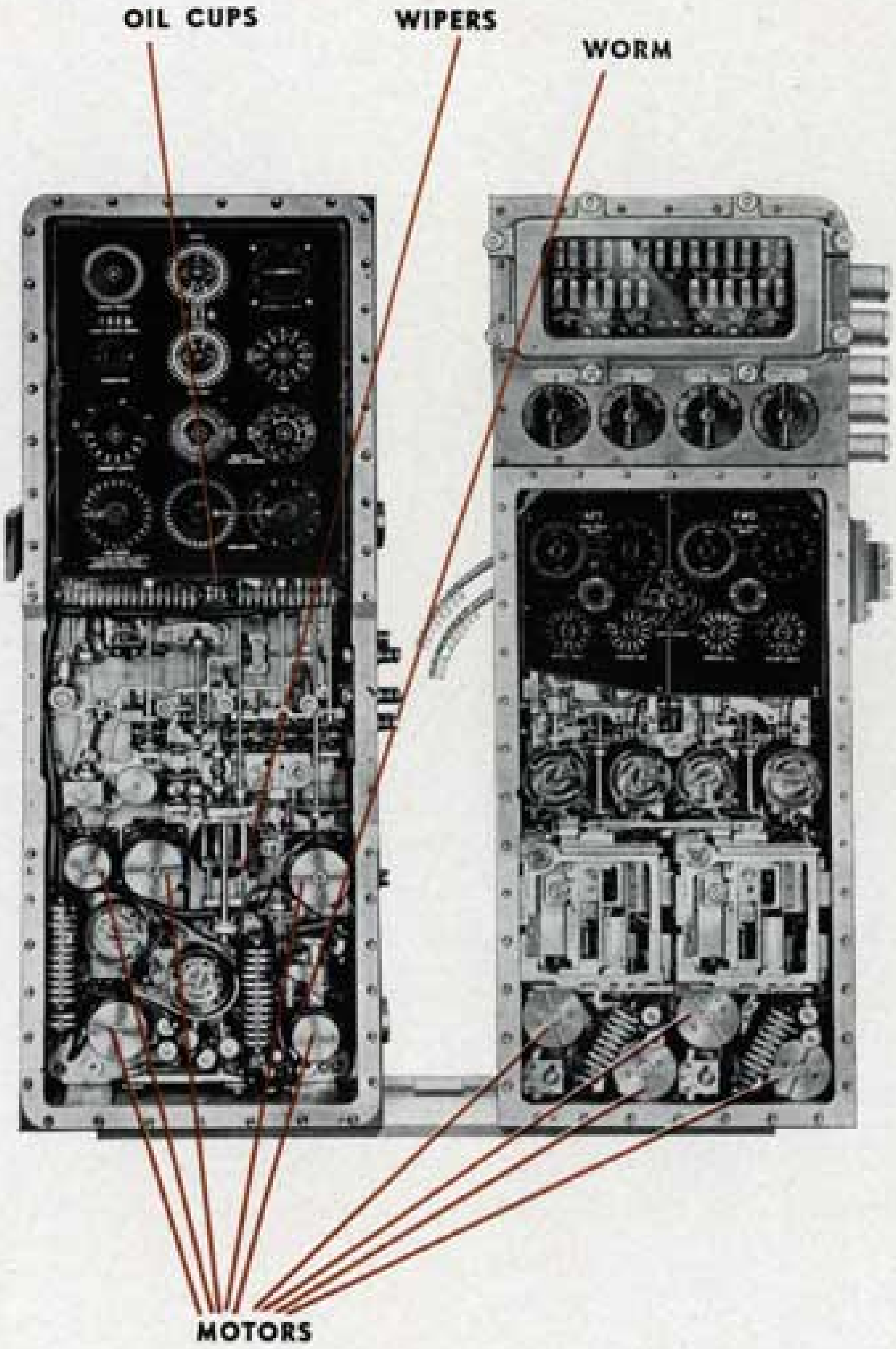


Fig. 280

1. Lubricate the oiling system of the discs and rollers of the Integrator Unit by inserting several drops of Navy Lubricant #2075 in each of the six oil cups which are located behind the lower edge of the upper cover of the Position Keeper.

2. Lubricate the oiling system of the disc and roller of the Divider Unit by inserting several drops of Navy Lubricant #2075 on the wipers which contact the disc and roller.

3. Lubricate the worm on the shaft of the Time Motor with Gulf Precision Grease No. 1. Use a grade B grease (Navy Spec. 14L3b), only, in the event that the recommended lubricant is not available.

MISCELLANEOUS

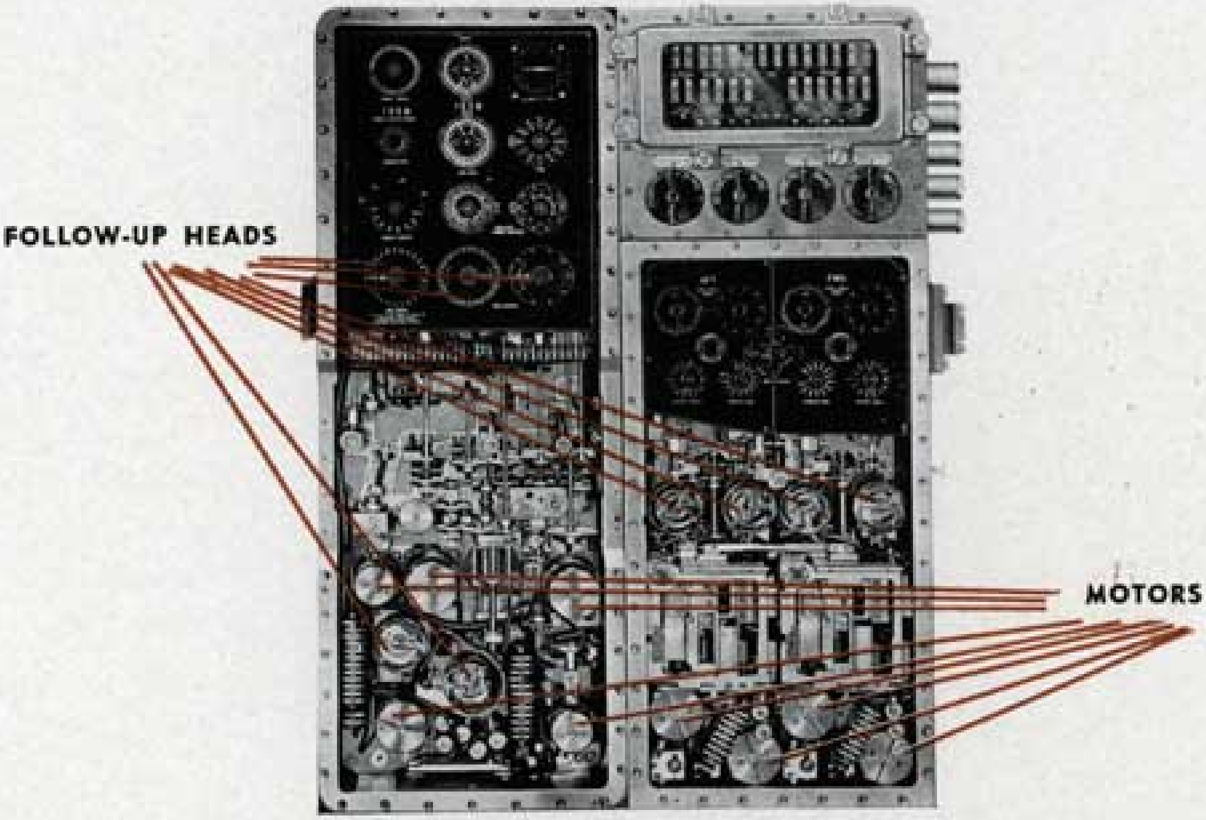


Fig. 281

1. The bearings of the Follow-up Motors, the Time Motor, the Governor, the Follow-up Heads, and other miscellaneous bearings should be packed with Gulf Precision Grease No. 1 during the period of routine overhaul, or in case the instrument is disassembled for any other reason. When the instrument leaves the factory these bearings are lubricated with this lubricant and it is recommended for subsequent use when available. Use a grade B grease (Navy Spec. 14L3b), only, in the event that the recommended lubricant is not available.

2. All of the gears worms, worm wheels and Stop screws with traveling nuts should be lubricated with Gulf Precision Grease No. 1 during the period of routine overhaul. Use a grade B grease (Navy Spec. 14L3b), only, in the event that the recommended lubricant is not available.

APPENDIX

There are certain data pertaining to the Computer, which cannot logically be placed in the foregoing sections, but which are nonetheless important. These items are all grouped under the heading, "Appendix."

SECTION 10

GENERAL INFORMATION

LOCATION	• In the control room of SS204 and 205, and in the conning tower of the other submarines.
DIMENSIONS	• 57¼″ high x 42″ wide and 17″ deep, all dimensions approximate and not including terminal tubes.
WEIGHT	• 1507 pounds.
TERMINAL TUBES	• Refer to elementary wiring diagram.
ELECTRIC CABLES	• Refer to elementary wiring diagram.
FUSES	• Fwd Gyro Angle Order Transmitters . . . Two 5 Amp. • Aft Gyro Angle Order Transmitters . . . . Two 5 Amp. • Fwd Gyro Setting Indicator . . . . Two 3 Amp. • Aft Gyro Setting Indicator . . . . Two 3 Amp. • Fwd Gyro Setting Regulator . . . . Two 3 Amp. • Aft Gyro Setting Regulator . . . . Two 3 Amp. • Fwd Gyro Angle Solver F.U. Motors . . . Two 5 Amp. • Aft Gyro Angle Solver F.U. Motors . . . . Two 5 Amp. • Own Course F.U. Motor . . . . Two 5 Amp. • Own Speed F.U. Motor . . . . Two 5 Amp. • Position Keeper F.U. Motors . . . . Two 10 Amp. • Heaters A. C. Supply . . . . Two 10 Amp. • Time System D. C. Supply . . . . Two 10 Amp.

APPENDIX

SIGNAL LIGHTS	• Fwd Correct Solution . . . Two TS49, 6 watt, 130 volt bulbs. • Aft Correct Solution . . . Two TS49, 6 watt, 130 volt bulbs. • Generating Light . . . Two VG-7, ¼ watt, 115 volt, neon bulbs. • 1 and 36-speed fwd Gyro Setting Indicator Overload Lights . . . One VG-7 neon bulb for each. • 1 and 36-speed aft Gyro Setting Indicator Overload Lights . . . One VG-7 neon bulb for each. • 1 and 36-speed fwd Gyro Setting Regulator Overload Lights . . . One VG-7 neon bulb for each. • 1 and 36-speed aft Gyro Setting Regulator Overload Lights . . . One VG-7 neon bulb for each.
SYNCHROS	• Generators . . . . Two 5G Mark 1 Mod. 1A. Two 6G Mark 2 Mod. 1A. • Motors . . . . Three 5N Mark 6 Mod. 1A.
FOLLOW-UP HEADS	• Synchro . . . . Two 3-ring and one 4-ring. • Mechanical . . . . Six 4-ring.
FOLLOW-UP MOTORS	• Three Arma type P21 • Five Arma Type J22
TIME MOTOR	• One modified Arma type J22 wound for D. C. Supply.

INPUTS AND OUTPUTS

HAND INPUTS	• Own Course . . . For use instead of synchro follow-up system . . . 90-speed, 4 degrees per turn. • Own Speed . . . For use instead of synchro follow-up system . . . 40-speed, one knot per turn. • Target Course . . . For initial and subsequent settings . . . 90-speed, 4 degrees per turn. • Target Speed . . . For initial and subsequent settings . . . 40-speed, one knot per turn.

- Target Bearing: For initial and subsequent settings . . . 90-speed, 4° per turn.
- Range: For initial and subsequent settings . . . 40-speed, 200 yards per turn.
- Target Length: For initial and subsequent settings . . . 30-speed, 50 feet per turn.
- Time Reset: For setting Time Dial back to zero . . . 60-speed, one minute per turn.
- Offset Angle fwd: For setting in desired fwd Offset Angle . . . 90-speed, 4° per turn.
- Offset Angle aft: For setting in desired aft Offset Angle . . . 90-speed, 4° per turn.
- Depth Set: For setting value of corrected Torpedo Speed, $S'z$, corresponding to Keel Depth . . . nine turns =10 knot correction.
- Keel Depth-Reach, M: For setting in the value of Reach corresponding to observed Keel Depth . . . 270 yards per turn.
- Keel Depth—Torpedo Run Difference, Uy: For setting in Torpedo Run Difference, Uy, corresponding to observed Keel Depth . . . 270 yards per turn.
- Radius of Turn: For setting in the Turning Radius of the torpedo to be released . . . 354 yards per turn.

ELECTRICAL INPUTS

- 115 volt A.C. supply circuit . . . From I.C. Switchboard.
- 115 volt D.C. supply circuit . . . From I.C. Switchboard.
- Own Course synchro signal for 1 and 36-speed synchro motors . . . From Gyro Compass.
- Own Speed synchro signal . . . From I.C. Switchboard.

ELECTRICAL OUTPUTS

- Fwd Gyro Angle Order at 1 and 36-speed . . . To fwd Gyro Setting Indicator Regulator.
- Aft Gyro Angle Order at 1 and 36-speed . . . To aft Gyro Setting Indicator Regulator.

DIAL AND COUNTER GRADUATIONS

DIAL GRADUATIONS

- Own Course: 1-speed . . . 360° per turn . . . graduated every 5° from 0° to 360° . . . numbered every 10° from 0° to 360°.
- Own Course: 36-speed . . . 10° per turn . . . graduated every 10' from 0° to 10° . . . numbered every degree from 0° to 10°.
- Own Speed: The Own Speed Dial is graduated to correspond to the synchro signal sent from the ship Log.
- Relative Target Bearing: 1-speed . . . 360° per turn . . . graduated every 5° from 0° to 360° . . . numbered every 10° from 0° to 360°.
- Relative Target Bearing: 36-speed . . . 10° per turn . . . graduated every 10' from 0° to 10° . . . numbered every degree from 0° to 10°.
- Relative Sound Bearing: 1-speed . . . 360° per turn . . . graduated every 5° from 0° to 360° . . . numbered every 10° from 0° to 360°.
- Relative Sound Bearing: 36-speed . . . 10° per turn . . . graduated every 10' from 0° to 10° . . . numbered every degree from 0° to 10°.
- Target Course: 1-speed . . . 360° per turn . . . graduated every 5° from 0° to 360° . . . numbered every 10° from 0° to 360°.
- Target Course: 36-speed . . . 10° per turn . . . graduated every 10' from 0° to 10° . . . numbered every degree from 0° to 10°.

*See Page 47 and explanation on Page 74 regarding Distance to Track Indicator and Dial.

- Target (Outer): 1-speed . . . 360° per turn . . . graduated every 2° from 0° to 360° . . . numbered every 10° from 0° to 360°.
- Target (Inner): 1-speed . . . 360° per turn . . . graduated every 2° from 0° to 360° . . . numbered every 10° from 0° to 360°.
- Own Ship (Outer): 1-speed . . . 360° per turn . . . graduated every 2° from 0° to 360° . . . numbered every 10° from 0° to 360°.
- Own Ship (Inner): 1-speed . . . 360° per turn . . . graduated every 2° from 0° to 360° . . . numbered every 10° from 0° to 360°.
- Target Speed: 44/45-speed . . . app. 41 knots per turn (Stop allows travel only from 0 to 40 knots) . . . graduated every ½ knot from 0 to 40 knots . . . numbered every knot from 0 to 40 knots.
- Time (Outer): 1-speed . . . 60 minutes per turn . . . graduated every minute from 0 to 60 minutes . . . numbered every 5 minutes from 0 to 60 minutes.
- Time (Inner): 1/60-speed . . . 60 seconds per turn . . . graduated every second from 0 to 60 seconds . . . numbered every 5 seconds from 0 to 60 seconds.
- Target Length: 1-speed . . . 1500 feet per turn (Stop prevents complete turn) . . . graduated every 20 feet from 300 to 1000 feet . . . numbered every 100 feet from 300 to 1000 feet.
- SR/1000 (on index plate): Graduated every 20 feet from 0 to 320 feet . . . numbered every 100 feet from 0 to 300 feet.
- Fwd Gyro Angle Order: 1-speed . . . 360° per turn . . . graduated every 5° from 0° to 360° . . . numbered every 10° from 0° to 360°.
- Fwd Gyro Angle Order: 36-speed . . . 10° per turn . . . graduated every 10' from 0° to 10° . . . numbered every degree from 0° to 10°.

- Aft Gyro Angle Order: 1-speed . . . 360° per turn . . . graduated every 5° from 0° to 360° . . . numbered every 10° from 0° to 360°.

- Aft Gyro Angle Order: 36-speed . . . 10° per turn . . . graduated every 10' from 0° to 10° . . . numbered every degree from 0° to 10°.

- Fwd Offset Angle: 5-speed . . . 72° per turn (Stop allows travel only from 0° to right or left 35°) . . . graduated every degree from 0° to right or left 35°. . . numbered every 5° from 0° to right or left 35°.

- Aft Offset Angle: 5-speed . . . 72° per turn (Stop allows travel only from 0° to right or left 35°) . . . graduated every degree from 0° to right or left 35° . . . numbered every 5° from 0° to right or left 35°.

- Fwd or aft Torpedo Run: 9/8-speed . . . 7111 yards per turn . . . graduated every 100 yards from 300 to 6800 yards . . . numbered every 500 yards from 500 to 6500 yards.

- Depth Set: Transparent dial graduated every 5 feet from 10 to 50 feet for Mk. 10 Mod. 3, Mk. 14, Mk. 14 Mod. 1 and Mk. 15 Torpedoes.

- Torpedo Speed: 1-speed . . . 40 knots per turn . . . graduated every knot from 25 to 60 knots . . . numbered every 5 knots from 25 to 60 knots.

- Sound Base Line: Graduated every 2 yards from 0 to fwd or aft 32 yards . . . numbered every 10 yards from 0 to fwd or aft 30 yards.

- Keel Depth-Reach, M: 270 yards per turn . . . Reach graduated on face of hand knob every 2 yards from −50 to +200 yards and numbered every 20 yards from −40 to +200 yards. Keel Depth graduated on a removable, peripheral scale . . . Scales are provided for Mk. 14, Mk. 14 Mod. 1 and Mk. 15 Torpedoes.

- Keel Depth—Torpedo Run Difference, Uy: 270 yards per turn . . . Uy graduated on face of knob every 2 yards from 0 to 250 yards and numbered every 20 yards from 0 to 240 yards . . . Keel Depth graduated on a removable, peripheral scale . . . Scales are provided for Mk. 14 and Mk. 14 Mod. 1 torpedoes.
- Radius of Turn: 354 yards per turn . . . graduated every 2 yards from 75 to 400 yards . . . numbered every 20 yards from 75 to 395 yards.
- Base Line: 162 yards per turn . . . graduated every yard from 0 to 100 yards . . . numbered every 10 yards from 0 to 100 yards.
- $Z_R - Z_L$: Linear scale . . . 200 yards per inch . . . graduated every 10 yards from 0 to ± 150 yards and numbered every 50 yards from 0 to ± 150 yards. Circular scale . . . 50 yards per turn . . . graduated every yard and numbered every 10 yards from 0 to ± 50 yards.
- $M_R - M_L$: Linear scale . . . 200 yards per inch . . . graduated every 10 yards from 0 to ± 150 yards and numbered every 50 yards from 0 to ± 150 yards. Circular scale . . . 50 yards per turn . . . graduated every yard and numbered every 10 yards from 0 to ± 50 yards.

COUNTER GRADUATIONS

- Range: 10,000 yards per turn (Stop allows travel only from 0 to 8000 yards) . . . graduated every 2 yards from 0 to 9998 yards . . . numbered every 10 yards from 0 to 9990 yards.
- Angle Solver Range: 10,000 yards per turn (Stop allows travel only from 300 to 8000 yards) . . . graduated every 2 yards from 0 to 9998 yards . . . numbered every 10 yards from 0 to 9990 yards.
- Total Running Time: 10,000 hours per turn . . . numbered every 1/10 hour from 0000.0 to 9999.9 hours . . . 10 revolutions of shaft counts 1/10 hour on counter.

APPENDIX

RELATIVE SPEEDS:

- Angles. 1-speed means that one turn is equivalent to 360° of basic quantity.
- Range: 1-speed means that one turn is equivalent to 8000 yards.
- Speed: 1-speed means that one turn is equivalent to 40 knots.
- Target Length: 1-speed means that one turn is equivalent to 1500 feet.
- Time: 1-speed means that one turn is equivalent to 60 minutes.

PRINCIPAL DRAWINGS

LIST OF DRAWINGS	BUR. ORD. NO.
Mk. 3 Mods. 5, 6, 7, 8 & 9	Sk. No. 93483
Mk. 3 Mods. 10 & 11	Sk. No. 93585
Mk. 3 Mod. 12	Sk. No. 93586
Functional Diagram	291806
Angle Solver Gear Diagram	291805
Position Keeper Gear Diagram	291230
Elementary Wiring Diagram: Mk. 3 Mods. 5, 6, 7, 8, 10, 11 & 12	269627
Mk. 3 Mod. 9	290910
Angle Solver Internal Wiring Diagram	291871
Position Keeper Internal Wiring Diagram	269717
Outline: Mk. 3 Mods. 5, 6, 7, 8, 10, 11 & 12	291807
Mk. 3 Mod. 9	291592
Arma type P21 Follow-up Motor	198746
Arma type J22 Follow-up Motor	212925

5N Synchro Ordnance Description	O.D. No. 2598
5G Synchro Ordnance Description	O.D. No. 2598
6G Synchro Ordnance Description	O.D. No. 2598

ELEMENT NUMBERS

POSITION KEEPER

ELEMENT	ELEMENT NUMBER
Synchro Motor, 1-speed, Co	1
Synchro Motor, 36-speed, Co	2
Follow-up Head and Dial, 1-speed, Co	3
Follow-up Head and Dial, 36-speed, Co	4
Follow-up Motor, Co	5
Differential for Time Reset	6
Differential, Br	7
Handcrank, Co	8
Follow-up Switch, Co	9
Dial, 1-speed, Br	10
Dial, 36-speed, Br	11
Dials, Own Ship	12
Resolver, sin Br and cos Br	13
Integrator, $\int So \sin Br\, dT$	14
Integrator, $\int So \cos Br\, dT$	15
Synchro Motor, So	16
Follow-up Head and Dial, So	17
Follow-up Motor, So	18
Stop, So	19
Integrator, $\int So\, dT$	20
Handcrank, So	21
Follow-up Switch, So	22
Time Motor, dT	23
Time Motor Governor	24
Integrator, $\int S\, dT$	25
Dials, T	26
Handcrank for Time Reset	27
Differential, R$\triangle$B	28
Differential, $\triangle$R	29
Dials, Target	30
Handcrank, C	31
Dial, C	32
Differential, A	33
Resolver, sin A and cos A	34
Integrator, sin A and $\int S \sin A\, dT$	35

ELEMENT	ELEMENT NUMBER
Stop, fwd or aft	1FA
Resolver, fwd or aft, R sin(G−Br) and R cos(G−Br)	2FA
Differential, fwd or aft, R cos(G−Br)−H cos I	3FA
Follow-up Head, fwd or aft, Us+P cos G	4FA
Handcrank, fwd and aft, Sh	5F-A*
Dial, fwd and aft, S'z and Depth Set	6F-A*
Stop, fwd or aft, S'z	7FA
Proportionator, fwd or aft, H	8FA
Follow-up Motor, fwd or aft, T'a	9FA
Stop, fwd or aft, T'a	10FA
Dial, fwd or aft, Us+Ug	11FA
Dial, fwd or aft, 1-speed, Gyro Angle Order	12FA
Dial, fwd or aft, 36-speed, Gyro Angle Order	13FA
Differential, fwd or aft, Us+P cos G	14FA
Stop, fwd or aft, S	15FA
Resolver, fwd or aft, H sin I and H cos I	16FA
Differential, fwd or aft, I	17FA
Differential, fwd or aft, R sin(G−Br)−H sin I	18FA
Follow-up Head, fwd or aft, J+P sin G	19FA
Follow-up Motor, fwd or aft, G−Br	20FA
Stop, fwd or aft, G−Br	21FA
Differential, fwd or aft, G	22FA
Differential, fwd or aft, G+L	23FA
Differential, fwd or aft, J	24FA
Differential, fwd or aft, Ug	25FA
Handcrank, fwd or aft, L	26FA
Dial, fwd or aft, L	27FA
Stop, fwd or aft, L	28FA
Synchro Generator, fwd or aft, 1-speed, Gyro Angle Order	29FA
Synchro Generator, fwd or aft, 36-speed, Gyro Angle Order	30FA
Correct Solution Light, fwd or aft	31FA

ELEMENT	ELEMENT NUMBER
Torpedo Gyro Angle Order Switch, fwd or aft	32FA
Hand Knob, fwd and aft, Keel Depth, Uy	33F-A*
Stop, fwd and aft, Uy	34F-A*
Differential, fwd or aft, $Ug - P\cos G$	35FA
Gyro Angle Correct Solution Light Cut-out Switch	36FA
Torpedo Run Correct Solution Light Cut-out Switch	37FA
Offset Angle Zero Detent Switch	38FA
Offset Angle Zero Detent Solenoid	39FA
Hand Knob, fwd and aft, Keel Depth, Reach	40F-A*
Stop, fwd and aft, Reach	41F-A*
Hand Knob, fwd and aft, Turning Radius	42F-A*
Stop, fwd and aft, Turning Radius	43F-A*
Differential, fwd or aft, $Us + Ug$	44FA
Differential, fwd or aft, $J + P\sin G$	45FA
Cam, fwd or aft, $Z(\pi G/180 - \sin G)$	46FA
Cam, fwd or aft, $M(1 - \cos G)$	47FA
Cam, fwd or aft, $Z(1 - \cos G)$	48FA
Cam, fwd or aft, $M\sin G$	49FA
Adjusting Screw, fwd or aft, $Z_R - Z_L$	50FA
Scale, fwd or aft, $Z_R - Z_L$	51FA
Adjusting Screw, fwd or aft, $M_R - M_L$	52FA
Scale, fwd or aft, $M_R - M_L$	53FA
Z Cam Carriage, fwd or aft	54FA
M Cam Carriage, fwd or aft	55FA
Adjusting Ring, fwd or aft, Base Line	56FA
Resolver, fwd or aft, $P\sin G$ and $P\cos G$	57FA

***NOTE:** The fwd and aft Angle Solvers are essentially the same. The letters "FA" after the element numbers indicate that the description applies to either Angle Solver. The letters "F-A" indicate that the element applies to both Angle Solvers simultaneously.

EXERCISING AND LUBRICATION OF STORED INSTRUMENTS

To insure that each gear and ball bearing rotate at least once, and thus distribute the lubricants properly, the following operations should be performed each month.

Exercising the instrument requires that it be connected to a 115 volt A.C. supply and to a 115 volt D.C. supply. These connections will be made to the terminal blocks behind the fuse panel. Open the window in front of the fuse panel, then loosen the two thumbnuts on the fuse panel and swing the panel outward to expose the terminal blocks. Connect the 115 volt A.C. lines to the terminals marked AC and ACC. Connect the positive 115 volt D.C. lead to the terminal marked DC and the negative lead to the terminal marked DCC.

Turn the power switch to the "Position Keeper and Angle Solver" position as marked in white letters. Turn the handcranks as indicated below:

HANDCRANK DESIGNATION	NUMBER OF TURNS
Target speed	Hit both ends of stop
Range	Hit both ends of stop
Target Length	Hit both ends of stop
Own Speed	Hit both ends of stop
Target Bearing	90 turns
Target Course	90 turns
Own Course	90 turns
Time Reset	60 turns
Offset Angle (Fwd & Aft)	Hit both ends of stop
Depth Speed	Hit both ends of stop
Keel Depth, Uy	Hit both ends of stop
Keel Depth, M Reach	Hit both ends of stop
Radius of Turn	Hit both ends of stop

Turn the power switch to the "OFF" position.

Every two months, remove the glass cover from the Position Keeper and turn the inner Own Course and Own Speed dials by hand several revolutions.

In addition to these exercises, the instrument must be lubricated every year as follows: Remove the upper and lower covers of the Position Keeper. Oil the discs and rollers of the Integrator unit by putting several drops of Navy lubricant No. 2075 in each of the six Gits Oilers which are located just below the dial index plate. Oil the disc and roller of the divider unit, which is located in the lower part of the case, by putting several drops of Navy lubricant No. 2075 on the felt wipers which contact the disc and roller.

APPENDIX

DISTRIBUTION

Requests for additional copies of OP 1056 should be directed to the nearest BuOrd Publications Distribution Center: Navy Yard, Washington, D.C.; Mare Island, California; Adak, Alaska; Pearl Harbor, Hawaii; Espiritu Santo, New Hebrides; Exeter, England; Brisbane, Australia. Distribution Center mailing addresses should be obtained from list 10 nn on the Standard Navy Distribution List.

Standard Navy Distribution List No. 23
2 copies each unless otherwise noted.

1.a,f,h,k; 2.r,u; 3.nn*,pp; 4.mm*,pp; 5.b; 7.f-h,1*; 7.(5 copies),b*; 7.(10 copies),a; 8.h,n(SPECIAL LIST F,X,AA); 10.(25 copies),nn; 12.a,b(Revision 1); 14.q;

SS 167-544 incl.
7.b(Naval Station, Key West, Fla. only)
7.1(SubBases and SubRepair Units)

*Applicable Addressees